INFORMATION NEEDS AND HABITS OF UNAFFILIATED KNOWLEDGE WORKERS IN THE UNITED KINGDOM

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DECLARATION OF ORIGINALITY

I, David John Brown, confirm that the work presented in this thesis is my own. Where information has been derived from other sources I confirm that this has been indicated in the thesis.

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ABSTRACT

The aim of this thesis is to analyse difficulties facing researchers excluded from results of mainstream academic research or corporate R&D, and offer recommendations on how they (unaffiliated knowledge workers or UKWs) can be integrated into future scientific activity. It also investigates the contextual aspect of whether science communication itself (science, technology, engineering and medicine or STEM) has become dysfunctional. This arises from claims that barriers prevent current stakeholders reaching into the professions, SMEs and citizen scientists - all parts of the UKW sector - with formal research publications. However, these barriers are now being breached through the combined effects of technological developments, social adaptation, administrative/legal changes and adoption of radical commercial/business models. This is leading to a migration from a print culture through a hybrid publications system to a fully digital environment where information needs will be met by different processes and procedures. The conclusion is that a paradigm shift is underway. The existing differences between STEM sectors - publishers, librarians, funders, intermediaries - over operational issues is preventing longer-term threats being addressed. The recommendation is that strategic delphic studies be undertaken at national and industry levels to provide alternative visions for STEM publishing, to support a smooth transition to a digital information economy. Included among these studies is the need to incorporate knowledge workers within the research system to produce a broader, healthier and more sustainable market for STEM. There is also a moral issue facing STEM - whether migration to an open, free and democratic system for creating information as a public utility, in line with Internet culture, can be reconciled with the drive to generate revenues and profits to sustain the commercial basis of the publishing industry; whether STEM in future should be liberated and made a ‘free’ utility.

TABLE OF CONTENTS

TABLES

GRAPHS AND MODELS

ACKNOWLEDGEMENTS

Appreciating the challenges facing researchers in accessing research outputs was sought through a research project awarded to CIBER (UCL) in 2010 by a consortium of the Research Information Network (RIN), Joint Information Services Committee (Jisc), and the Publishing Research Consortium (PRC). The 'Gaps and Barriers' project (Rowlands and Nicholas, 2011) had as its theme issues similar to those being addressed in this thesis. As a member of the research team in the 'Gaps' project this author investigated researchers' information activities and what additional empirical research would be required to understand their needs and habits. The interaction with Professor David Nicholas (CIBER) and Dr Ian Rowlands on the Gaps project was valuable in setting the scene for this MPhil thesis.

However, interest in this topic dates back further, seven to eight years, whilst the author was a member of the senior management executive team at the British Library, and awareness arose of the challenges which broad sectors of UK society faced in accessing published research literature. Discussions with the then director of information technology at the British Library, Richard Boulderstone, highlighted the distinction between elitism and democracy as underlying themes within the STEM industry. Prior to the British Library the author spent ten years undertaking market research and business development within Elsevier Science in Amsterdam, and subsequently with Pergamon Press in Oxford. Contacts maintained with Elsevierian staff and its alumni has assisted in enabling current publishing perspectives to be included. The author was also director in several international intermediaries in the scientific communication arena both in the UK and USA. As director of the Ingenta Institute in the early 2000's the author organised conferences to explore future developments in the information industry with the support of Ingenta's CEO (Mark Rowse), and this interest was encapsulated as co-editor, together with Albert Prior, of a newsletter entitled *Scholarly Communications Report* which was published monthly from 1998 to 2010.

Therefore, the issues addressed in this thesis are viewed from the perspectives of the main stakeholders in the scientific information industry – publisher, librarian, intermediary, quasi-journalist and most recently as honorary research

associate at UCL - and the views are not restricted to, nor promoted by, any one group or sector of the information society. The issues tackled in this study are such that an independent approach was vital, one without a preconceived agenda.

More recently, Professor David Bawden (City University) accepted the task of becoming primary supervisor for this MPhil project, and his help and guidance, along with Professor Vanda Broughton from the Department of Information Studies at University College London (UCL), has been much appreciated. In particular, they have advised on how the complex issues involved in this study should be formulated in the mold required of a postgraduate thesis.

Many other external experts were contacted for their views. However, none bears responsibility for the structure of the thesis, nor its content, interpretations, conclusions nor recommendations. Though research ethics of ensuring that comments from those interviewed were accurately encapsulated, it is nonetheless a post-positivist assessment of the current state of scientific publishing overlain by as much hard evidence as is available in support of the main finding that change is imminent, substantial and affects a wide spectrum of research communication activities in the near future. Key among these is the impact change will have on ‘unaffiliated knowledge workers’ or UKWs. The scientific information (scientific, technical, engineering and medical, or STEM) needs of individuals in these communities is the primary target for this investigation.

The assistance from UCL and the many other individuals who gave their time in offering advice, opinions and support - many of whom are referred to in the text - is recognised, appreciated and acknowledged where appropriate.

1. INTRODUCTION

1.1. TOPIC SELECTION FOR THIS THESIS

Funding agencies and the media have focused on the immediate commercial challenges facing the STEM information system. Comparatively little attention has been given to longer term strategic issues – for example, optimising research output formats to meet existing and new user demand in a digital world, or on attracting participation from groups having wider more practical or applied but nevertheless relevant skill sets, or identifying the status and role of STEM as a utility within society. This thesis investigates such longer term issues – in particular, whether communities of knowledge workers could be incorporated more readily into the national scientific effort if appropriate changes were undertaken, and what this would mean for the health of the scientific information process and the commercial viability of stakeholders involved. In theory, participation by knowledge workers and a more 'research aware' public could enhance R&D efficiency and result in the generation of additional outcomes and resources which would feed back to support future funding activities in R&D. This scenario needs to be tested.

The efficacy or inefficiencies of the current STEM publication system has been highlighted by *The Guardian* journalists Monbiot (2011) and Brown, A (2009); by academics such as Gowers (2014), Murray Rust (2014) and Allington (2013); by independent observers such as the Sussskinds (2015); by government agencies such as the UK Office of Fair Trading (UKOFT, 2002); by Jisc, and within the Finch report (RIN, 2012). Also, by American commentators such as Neilsen (2009), Esposito (2013) and Shirky (2008) among many others (see chapter 4.1.2 in Literature Review). These informed commentators have pointed to weaknesses within the STEM information system in the evolving socio/technical context.

Personal experience by the author in the information industry was also a determining factor in investigating this topic. The impression reached as a result of the author's background of almost forty years in this industry was that scientific publishing has established itself as a niche service catering for an 'elitist' academic clientèle, whereas new technology and social change suggest that greater 'democratisation' of research outputs could bring additional and novel benefits to UK science and society. A sociological as much as a technological revolution is taking place. It is claimed that these issues have not been brought together in recent years in a holistic, impartial or structured way to reflect both current activity and future trends in STEM.

The benefits in analysing this topic are timely and profound at this juncture. Research paradigms are shifting and print competes with digital information for researchers' attention. It raises questions about the current political focus on an 'open access' led STEM publishing system and whether this should be set against the greater social returns coming from a broader democratic focus which includes informal social media and high-tech led services being developed and promoted by stakeholders. It will be reported on whether the existing infrastructure for STEM is fit for purpose, and whether commercial STEM publishers and professional societies in particular need to revisit their traditional corporate missions and adapt to the ubiquitous digital world. As will be explained in the following thesis, scientific communication is currently in a volatile and potentially vulnerable state.

The need for the system to be fixed is highlighted by the results of a recent Ithica S&R "Survey on UK academics" (Ithica, 2016) which reported "There is a growing interest from academics in reaching audiences outside those in academia with their research [findings]". Compared with an earlier Ithica study in 2012 there has been a significant increase in respondents who indicated that professionals outside of academia, undergraduate students and the general public are all very important audiences to reach with research findings. These wider communities of potential users have not been taken into account in the marketing strategies adopted by STEM publishers in the past.

The above were the starting points, providing both the stimulus and setting the conceptual framework for this thesis.

1.2. DEFINITIONS

The following terms and acronyms have been used throughout the thesis and are defined here to ensure consistency in use, particularly related to the sectors of science, technical, engineering and medical (STEM) research publications and unaffiliated knowledge workers (UKWs). These definitions are derived from published sources and are representative of terms used and understood within the STEM industry.

1.2.1. STEM, STM, sci/tech/med, S/E.

Several acronyms have traditionally been applied to this scientific niche. The preferred term for this project is 'STEM' - science, technology, engineering and medicine. Other acronyms used elsewhere include STM (often also associated with the International Association of STM Publishers). S/E is science and engineering and used by the National Science Foundation in its data compilations on the US information industry. Sci/tech/med is another label often applied, as is scientific publishing generally. This thesis is about communicating the results, or outputs, from scientific research to a wider audience or community.

STEM is a specialist publishing sector and a subset of a broader scholarly communications industry. The term scholarly publishing is used when softer sciences (humanities, social sciences, arts) are also included though the latter face different publishing issues from STEM. Both STEM and scholarly publishing are in turn a subset of the overall information economy. As a high-level specialist group scientific researchers have unique and specialised information-support needs which distinguish them from other parts of the larger academic and trade publishing sectors.

1.2.2. New Audiences

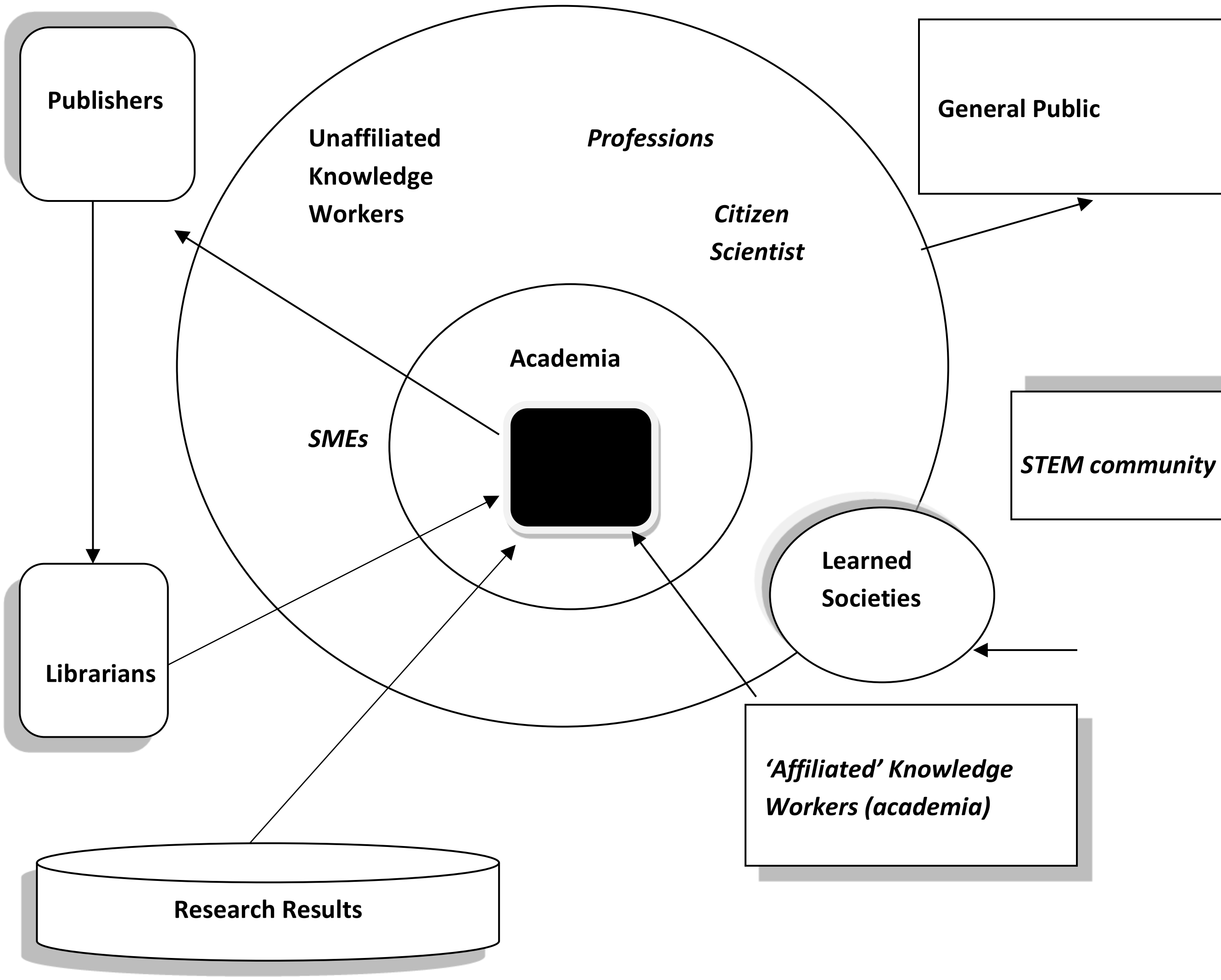
Using the term 'disenfranchised' to highlight new audiences is pejorative. 'Unaffiliated' is a less emotive term. Both convey that there are audiences 'outside the garden walls of academia', not beneficiaries of the closed academic/scientific information system which sees its publications acquired by, and channeled through, a network served by specialised research libraries. It is the aim of this thesis, by reaching out to a broader audience - such as unaffiliated knowledge workers or UKWs – and enabling similar access rights (administrative, technical, physical and commercial) as those which are available within academia, that this would improve the overall national knowledge base and make UKWs more productive and fulfilled.

There are several areas which will be highlighted for such ‘unaffiliated’ potential information users. These include:

- Professions, notably those having formal, scientific-based entrance standards and with stipulations to undertake certification, ensuring technical evaluations are followed, providing re-assessments, and updates.
- SMEs, small and medium enterprises, where there is a strong research or innovative component so that the organisation can remain competitive.
- Citizen scientists - those individuals who have passed through a higher education/skills system, taken up a career elsewhere, but for a variety of reasons wish to be kept involved of the results of relevant scientific research.
- Individuals whose careers involve their being based in remote locations or being out-of-office, such as engineers in the field. This also includes distance learners studying for higher qualifications.
- Patients who wish to keep informed and updated on procedures affecting medical complaints from which they or their relatives/friends are suffering.
- Administrators, policy makers, consultants, advisers, charities and other intermediaries who keep a watching brief on national scientific information policies.
- Researchers in third world countries – though outside the scope of this (UK-focused) thesis, any strategies or business models to improve STEM access appropriate for poorer countries could also have relevance for UKWs in the UK.

Not all these unaffiliated knowledge worker (UKW) areas will be investigated in this thesis. The above listing illustrates the breadth of the potential market for access to research results. The main targets being focused on in this instance are the professionals, SMEs and citizen or amateur scientists, with consideration also being given to unaffiliated academics and the general public.

Graph 1.1. Audiences for Scientific Information



1.2.3. Knowledge Workers

The definition for Knowledge Workers within Wikipedia is:

> "Knowledge workers in today's workforce are individuals who are valued for their ability to act and communicate with knowledge within a specific subject area. …… Fuelled by their expertise and insight, they work to solve those problems, in an effort to influence company decisions, priorities and strategies.
>
> "Knowledge workers may be found across a variety of information technology roles, but also among professionals such as teachers, librarians, lawyers,

architects, physicians, nurses, engineers, and scientists". (Source: Wikipedia)

The Wikipedia definition includes both scholars in academia as well as knowledge workers in wider society. The 'disintermediated' or UKWs are a subset of the global knowledge worker community. They also rely on having access to latest STEM research output to remain up-to-date.

It potentially heralds in an age of an extensive network of information users with a strong need for easy access to scholarship. Knowledge workers are a diverse and diffuse group of communities. In the United States, for example, science and engineers ranged from an estimated 5 million to 19 million (NSF, 2014) depending on how broadly the knowledge worker sector is defined. In the UK, the Office of National Statistics gives a figure of 11.1 million for knowledge workers (ONS, 2011). They are a social sector whose STEM information requirements needs to be taken into account.

1.2.4. Learned Societies

Learned societies are a paradigm for a community of like-minded individuals having a common mission. Learned societies establish an organisational structure, an information culture, and ingrained social responsibilities (see Chapter 7) which their members buy into. However, professions are changing and learned societies face similar challenges to their status and operations as those facing STEM. Social and technical disruption requires them to adapt to the new digital age (Susskind, 2015 and chapter 5.4.3).

Several professional societies depend for their viability on a commercial approach to publishing. This is so that they have the resources to build on their core social missions. Achieving an acceptable balance between providing relevant, targeted social services and yet also ensuring commercial sustainability, is a difficult challenge within a volatile information environment.

However, there are many learned societies emerging. As 'twigging' (the evolution of research areas into several component parts) encourages the creation of new sub disciplines so practitioners in these new research areas collaborate in creating their own journals, culture, procedures and learned society (see section 6.4.2.2). The Directory of British Associations and Associations in

Ireland (CBD, 2009) lists over 10,000 such institutions (though most do not have a strong scientific focus).

1.2.5. Media and Formats

The model adopted by STEM is for scientific research results to be published as articles in learned journals. There are other formats within the scientific communication process – conference proceedings, data and datasets, mash-ups involving integration of a number of media elements, supplementary material, grey literature or unrefereed publications, e-theses, patents, audio-visual presentations, conferences/meetings (actual and virtual), laboratory notes, etc. Each of these have distinctive roles but research articles have been the mainstay in reporting scientific progress.

Nevertheless, social media is now spawning new information carriers. These range from blogs through bulletin boards and listservs, to groups which create their own bespoke online forums to share information and ideas about topics of common interest. *Twitter, FaceBook, LinkedIn, Mendeley,* and *ResearchGate* are exemplars of the new formats, platforms and services that migration to digital information services has facilitated. Teleconferencing and webinars have also become centre stage for communicating the results for specific types of scientific research. Such new product formats and carriers are referred to as alternative or 'informal' scientific media.

These alternatives may be appropriate for meeting future information needs of groups of UKWs. This is where the clash is beginning to occur - between traditional academic approaches, and the new Internet advances, with the battleground being formats, business models and ease of accessibility (see sections 6.4.1 to 6.4.5).

Research Journals

Since the first scientific journals were launched, the mechanism whereby research output has been disseminated has been the Learned Journal. In England it started with Henry Oldenburg who became the first secretary of the newly established Royal Society in London in 1660. He was the founding editor of the society's journal, *Philosophical Transactions of the Royal Society,* in 1665.

Oldenburg persuaded fellow scientists to submit manuscripts to the new journal (Hall, 2002; p159). Submitted manuscripts were sent to experts in the field who made judgements about their quality before publication was agreed. This refereeing process sifted for quality. It was the beginning of both the modern scientific journal and the practice of peer review.

Over a thousand journal titles were established in the 18th century, and the number has increased since then to an estimated 28,100 active, scholarly peer-reviewed journals published by between 5,000 and 10,000 journal publishers by mid 2012 (Ware & Mabe, 2009a and 2012b).

During the past three and a half centuries there has been little change in the functions of journals. They include initial registration of research results; claiming precedence over the research; certification that the research results are correct, as arbitrated through review by peers prior to publication; archiving of the results in a structured and traceable manner; and dissemination of the publication to all those entitled to receive it. Online navigation and in-house editorial support services have been added to these functions in recent years (see chapter 6.5).

Primary research articles tend to be highly technical, representing the latest theoretical research and experimental results in the field of science covered by the journal. They are claimed to be incomprehensible to anyone except researchers in the field, though the extent of this is challenged as we enter an era of increasingly informed and educated knowledge workers (see section 5.10.2).

Tertiary reviews, written by specialists in the field, attempt to bridge the gap between high level research outputs and knowledge workers. Reviews are a transformative device, translating research results in a manner which can be understood by a broader audience. Translating latest specialised research output into the mainstream public information system is slow, expensive and lacks author motivation. Occasionally the trade press and newspapers pick up on important results (see 5.8.2) and make their own interpretations often with a selective agenda.

Overall, the scientific journal is largely a static vehicle which became essential in a print-based information world, but is challenged as internet and web create a dynamic and volatile environment within which researchers and knowledge workers increasingly operate.

1.2.6. Purchase and Access

There are several current barriers - commercial, technical, administrative, editorial - facing academic researchers seeking access to STEM journals (Rowlands and Nicholas, 2011). An important barrier is commercial (journal pricing). The subscription model for journal purchase, and its derivative 'the big deal', has become the principal means for determining researchers' entitlements to access the world's research findings.

This thesis investigates other STEM business models which are currently in place, as well as assessing emerging business models particularly those which may bring UKWs into the scientific research effort (see section 6.2). The issue of 'openness' in a generic sense pervades an increasingly Internet-focused society and is beginning to impact on scientific communications. The interaction between the Internet convention of free access in the non-affiliated sector against the traditional convention for sifting and quality control (at a cost) in scientific literature, is an area of growing uncertainty and concern within STEM.

Access can be defined in the context of inclusiveness. If basic research is to be used for improvement in society, such needs require articulation. This in turn demands involvement from a wider community than that which currently set policies and direction for science in the UK. Science can only be inclusive if all parties at all levels (government, academic, UKWs and the general public) become involved. The inclusion of the non-academic community in the research process is only just emerging as web and science developments come into effect. It is also supported by social processes such as sharing and collaboration becoming more important within science (Big Science and collaboratories) - see chapter 5.9.3. These are healthy, if slow-moving, developments within STEM.

Summary

These definitions indicate that the focus of this thesis is on strategic challenges facing a particular sector of society - science and scientific communication - and how these are tackled in a more effective way. It is also considered how this can be accomplished within the context of environmental changes taking place - a 'perfect storm' (see chapter 4.2.5.1) - over which the sector has little influence.

The conclusion is that the stakeholders will need to take positive action in determining the shape and direction of STEM in future to avoid being buffeted by destructive trends, possibly being technologically side-lined and rendered obsolete. One option is to open up science to a greater democratic participation, notably by extending access to research results to unaffiliated knowledge workers.

2. AIMS AND OBJECTIVES

2.1. SCOPE

Several practical issues are covered in this analysis.

- This is a *UK-focused research project* even though the issues are global. Comparative international data in this area is lacking. It is hoped that future iterations of this project can build on the statistical templates and textual analysis which has been undertaken in this UK-focused thesis.

- This project is both *commercial* and *strategic* as well as *academic* in its approach. A commercial assessment of market size, trends and prevailing business models exposes aspects of the change currently occurring in STEM. The strategic focus assesses the viability of new digital means of communicating specialised information. Future investments in the STEM infrastructure will be dictated by how confident organisations are that there is a socially acceptable, commercially viable and strategically sustainable business model underlying the output of research results in future. These issues are tackled through the prism of an academic approach which includes independent and structural rigour.

- In terms of academic discipline, the study focuses on *information science* and *publishing studies* but also straddles *informatics, sociology of science* with *behavioural economics.* Psychology, social psychology and social networking all have parts to play in analysing the conflict between traditional STEM print legacy and its transformation into the emerging digital/Internet world.

- The thesis' content is based on *science, technology, engineering and medicine (stm, STM, S&E or STEM)* rather than broader scholarship, albeit recognising that there is a fragmented approach within STEM disciplines in their approach to digital information systems. A physicist is different, in information requirements, from a humanist; a biologist from an econometrician. Even within individual scientific disciplines there are different informational sub-cultures.

- It is an *independent, impartial study,* based on the experiences of the author who has been part of organisations which are involved in all stages of the research cycle – from publishing (at Elsevier, Pergamon), librarianship (the British Library), intermediaries (Faxon; Blackwells) to consultancy (DJB Associates), authorship (of books and editor of monthly newsletter) and postgraduate researcher (UCL). Relying on any one existing stakeholder or process to make balanced assessments would suffer from traditional cultures distorting the picture and also the approach taken. Impartiality is important at this juncture particularly when feelings are running high over activities of some stakeholders. Threats of boycotts against commercial journal publishers, often referred to in social media, reflect more the failings of the current system rather than promoting realistic solutions and sustainable and unbiased strategies for the future (see chapter 4.1.2).

2.2. AIMS

There is a triple aspect to this thesis – the first is to evaluate information needs and habits of so-called unaffiliated knowledge workers (UKWs) in the UK, and secondly to place this assessment in the context of the present STEM information system. Finally, the external developments, encapsulated within the term ‘perfect storm’, are analysed both in terms of implications on UKWs specifically and STEM industry generally.

All three aspects are linked. An analysis of the STEM information process will inform whether it is fit for purpose in a rapidly changing information world. It addresses the implications which the current structure of STEM has on those communities which are not included in the mainstream STEM effort. At stake is the health of science communication during the next decade as stakeholders cope with the combination of disruptive technologies and social change impacting on the current STEM industry structure. It raises questions about the development of effective UK national science, research and information policies.

The aim therefore is to evaluate contextual issues within which STEM operates. The competencies of the major stakeholders needed investigation. This involved desk research and discussions with industry representatives to expose the heritage or baggage which the STEM information system has inherited over the past four centuries of print domination (see chapter 6 – STM Information Industry Dysfunctionality). It also included a SWOT analysis of the main stakeholders (see section 8.4).

However, the primary aim of this MPhil project is to investigate whether exclusion is being practised on a sector of society which has become science-aware but so far not science-enfranchised. This thesis tests a claim that the existing STEM publishing system creates obstacles preventing researchers and knowledge workers in the UK from having equitable access to published research. It is claimed that unaffiliated knowledge workers (UKWs) are currently on the periphery of the STEM information system; they do not work within academic or large corporate institutions and are excluded from easy access to STEM. They are often singletons or active in small independent research units or practices. This has implications on their ability to become involved in leading edge research. Constraints created and enforced by publishers deny UKWs the ability to keep as informed as their academic-affiliated counterparts. There is no level playing field in STEM communication (see chapter 6). Several UKW sectors are affected, each having skills or expertises which could mesh in with a more collaborative and open science communication system. These peripheral users are part of the burgeoning knowledge worker community (see chapter 5). The claims that they are disenfranchised (in terms of information access) are analysed as a primary aim for this thesis.

A third aim is to catalogue the future external and internal trends – social, economic, technical, administrative, political – which may disrupt the existing STEM structure and affect UKW information needs. Several concepts are described which show how externalities can impact on science and its communication in a digital world . The suggestion is that there is a tsunami about to break over STEM as the ‘perfect storm’ forces coalesce in the next ten years (see section 5.9 for UKWs and section 6.4 for STEM).

In conclusion, recommendations based on the analyses which have been described as part of the above activities are given in chapter 9. This includes, for example, proposing alternative publication systems owned and operated by non-profit agencies such as learned societies (see chapter 7).

The conclusion also provides answers to questions which were raised at the outset of this MPhil project and to offer suggestions and recommendations for further analysis. The intention is to produce recommendations for scientific information and research communications to move forward using effective, viable and sustainable platforms which meet different requirements from both old and new stakeholders and for both established and new market sectors (see section 9.3).

2.3. OBJECTIVES

Derived from the above aims, the objectives for this project and thesis includes:

- Pinpointing the role which unaffiliated knowledge workers (UKWs) currently have in the STEM information process.
- Assessing the extent and nature of information requirements of knowledge workers within UK society
- Identifying factors which prevent knowledge workers from engaging in science research on an equal basis as academics and those in corporate R&D
- Establishing policies and strategies to enable unaffiliated knowledge workers to be more fully integrated into the overall scientific research system
- Providing an analysis of relevant statistical sources on demographic trends
- Monitoring patterns of usage of STEM research outputs
- Describing the impact on the STEM industry resulting from the migration from print through hybrid to digital publishing
- Identifying public concerns expressed by recognised experts regarding the current STEM publication process, and assessing their respective relevancies
- Exposing the culture conflict between elitism and democracy in facilitating or preventing STEM information exchange
- Bringing together those publishing, financial and policy concepts which offer understanding about the extent and direction of emerging trends in STEM communications
- Reviewing the emerging technical options for STEM which developments in IT and the internet are creating
- Reviewing the impact which social media and social networking has in transforming the publication process

- Assessing the impact of the various open access routes on facilitating ease and freedom of access
- Evaluating the results which the changing nature of STEM communications will have on existing stakeholders (notably publishers, librarians and intermediaries)
- Reviewing the position of learned societies as providers of innovative STEM services

The aims and objectives of this investigation can be restated as giving a picture of the challenges facing unaffiliated knowledge workers (UKWs) in the UK and their prospects for gaining easy access to published scientific information within a climate of rapid sectoral change in the STEM sector.

2.4. RESEARCH QUESTIONS

Several research questions arose in the initial phase of this project which have been used as a template in approaching the topic of this MPhil. These were:

UKWs:

1. Who are those not benefiting from the current system of scientific publishing? What are the main sectors within unaffiliated knowledge workers?
2. What problems do each of these knowledge worker sectors have in getting access to formal published research results?
3. What needs to be done to enfranchise UKWs in the UK in future?

Social and technical trends:

4. What are the main information usage patterns found among scientific researchers?
5. How significant are underlying cultural and sociological trends in changing research activity and information needs?
6. How will researchers interact with social media in future in getting access to required STEM research results?
7. How will open access facilitate greater democratisation within STEM information?
8. What media – other than research journals – are used to keep

up-to-date

9. What are the main external drivers for change?

Supporting Agencies:

10. What role will learned societies have in supporting access?
11. What is the impact on existing stakeholders in meeting UKW researchers' information needs?

Industry Concerns:

12. How robust is the STEM publishing industry in the UK? Will it adapt and address information needs of a latent knowledge worker sector?
13. What are the opinions of leading industry observers concerning the main STEM publishing stakeholders?

Industry Structure:

14. What are the overall macro-level trends which are impacting on STEM communication?
15. What is the current structure of the information industry in the UK, specifically the research sector requiring access to scientific information.

This thesis will look at each of the above. Conclusions and recommendations will be provided at the end of the thesis (chapter 9).

2.5. OUTLINE OF THESIS

INTRODUCTION	This section describes the stimuli behind pursuing this topic as a MPhil project. It also gives definitions of the main terms used throughout the thesis
AIMS & OBJECTIVES	The aims and objectives - assessing the challenges facing unaffiliated knowledge workers (UKWs) in accessing STEM publications, and the problems facing the STEM publication industry itself - are described. A list of questions is raised (see above) which gave direction for the study and which require answers.

Answers based on evidence provided in the thesis are given in the Conclusions (chapter 9)

METHODOLOGY

The section on Methodology (chapter 3) outlines the stages which have been followed in this thesis, and subsequent chapters expand on how aspects of the overall methodological approach have been applied in relevant areas

LITERATURE REVIEW AND ANALYSIS

Several media types have been investigated in this thesis. Central has been a review of refereed, formal publications relating to the main topics of this thesis, but additional analysis has been made of discussions taking place in social media. Meetings and questionnaires have also been reported on in the relevant sections of the thesis to provide a multi-partite, triangular and a discourse analysis approach to this project. Demographic research has also been described.

RESULTS 1 - UKWs

This chapter describes not only the main segments of the UKW sector but also the current situation facing UKWs regarding their information access rights. Three areas are focused on with references made to two other related knowledge worker areas. An analysis of researcher behaviour and the main socio/technical trends affecting researchers in general and UKWs in particular has also been made.

RESULTS 2 - DYSFUNCTIONAL STEM

The STEM information industry, with the barriers to information access which it maintains, are outlined. This includes an analysis of business models used by different sections of the industry and the alternative information services being developed for researchers. Building on concepts and models described by industry pundits, a scenario is constructed which shows that

STEM faces new paradigms in a digital information world, and it needs to adapt.

RESULTS 3 - LEARNED SOCIETIES	Opportunities facing learned societies in taking greater control over STEM information dissemination are outlined in this chapter.
DISCUSSION	Key points emerging from the above analysis have been brought together and a SWOT analysis has been conducted on each of the main stakeholders in STEM. The commercial challenges facing publishers are also investigated.
CONCLUSIONS	A summary of the current situation facing UKWs is made. Recommendations for future action are also given in this chapter. Answers to the original Research Questions are included.
APPENDICES	A Bibliography of those items referred to in the thesis is provided. Also a list of Acronyms is included. Finally, two case studies are added which indicate the original source material compiled as part of the research for this thesis.

3. METHODOLOGY

During the initial scoping for this project, as outlined in section 2.1, an online literature review was undertaken which established that there was little formal, refereed published literature available relating specifically to the twin main related topics - STEM dysfunctionality, and needs of unaffiliated knowledge workers (UKWs).

Google was searched to identify relevant formal (refereed) research articles. Search terms included generic items – knowledge workers, scholarly publishing, and scientific researchers. In addition, a search of a subject-based online bibliographic database (A&I service) was undertaken – namely LISA: Library and Information Science Abstracts. The search terms used on LISA were barriers to scientific information access, international aspects of STEM and scientific end user behaviour which includes topics such as publishing, information management, knowledge management and telecommunications.

The results from both the global search engine and the subject specialist bibliographic database, though comprehensive in their coverage, gave limited insight or detail for this thesis.

In addition, the contextual nature of the information or knowledge economies was investigated. This included an assessment of works by leading classical information theorists who alerted the world to the importance of 'information' as a social asset. Their claims were updated by present experts on the information industry. Selection of experts has been based on those being close to the industry and the techno/socio developments facing STEM, and being recognised pundits with strong opinions about the direction STEM industry is taking.

Social media was used for topical, in many instances subjective anecdotal, input into the thesis. This source was valuable in that constraints which are part of the editorial process of primary journal publishing (such as editorial control and refereeing) are not featured in social media. Imagination and bold thinking are often found in the online discourse taking place on social media platforms and in social networking. Quantitative data has also been identified and collected, particularly as related to the demographic features of this study.

Meetings and online interviews were also held to drill down on usage behaviour among researchers to ensure that published research mirrored practical experiences.

The thesis was constructed on these inputs to assess how the current stakeholders in the STEM industry have adapted to the challenges created by the 'perfect storm' (see sections 5.9 and 6.4). A strength/weakness/opportunity/threat (SWOT) analysis was undertaken for each of the stakeholders (see section 8.4).

The above is strongly qualitative in its approach, with some quantitative input, leading to a critical analysis of the various descriptions, claims and opinions which in turn lead to the results, conclusions and recommendations outlined in Chapters 5 through 9.

3.1. Overall Research Approach

A mixed methods research (MMR) approach has been employed for this project. This is because the issues are complex and disparate, requiring a multifaceted approach. As will be described below in *Research Methodology* neither quantitative nor qualitative approaches on their own would be sufficient for an analysis of this topic; a combination (MMR) is essential. It is appreciated that the two research methodologies require different approaches, but this breadth has the advantage of enabling research in support of this thesis to include a variety of media formats, sources and online platforms.

The project includes an analysis of available published literature, both formal and informal. It also includes data collection and assessment from public resources. A third part of the research includes the use of online interviews using semi-structured questionnaires to identify researchers' behaviour patterns. Fourthly, meetings were held with experts representing the main STEM sectors, and a specific case study is described in the appendix which reflects the issues which the interviews highlighted. Finally, the Discussion chapter (chapter 8) raises controversial and complex issues which arise from the preceding chapters, with particular reference to the current STEM stakeholders.

3.2. Methodological approach

The methodological approach taken follows the guidelines outlined in textbooks describing research methods, in particular the overview given by Pickard (Pickard, 2013). More specific direction was provided by the following resources, and others cited later: Denscombe (2014) on desk research issues, by White & Marsh (2006) on content analysis, and Budd (2006) and Gale (2010) on discourse analysis.

This approach includes a description of the *research paradigm*, involving an 'objective assessment of the entire constellation of beliefs, values, techniques .... shared by the [knowledge worker] community' (Pickard, 2013). It is followed by the *research methodology* which gives a perspective on the practical approach taken. *Research methods* is then described before the *research technique* employed is outlined. The *research instruments* adopted, alluded to above in 'Overall approach' taken, concludes the description of the research method used in this thesis.

Later chapters also include a description of the specific research methodology applied in each chapter. The Table of Contents indicates that there are 16 instances throughout the thesis where the specific methodological approach taken has been elaborated on and applied to the particular topic being addressed.

All external contacts made during the course of the study were alerted to, and agreed to, the Research Ethics Framework required by University College London and its Code of Research Conduct. There are additional comments relating to constraints and limitations which were faced in undertaking this assignment.

Taking each of these steps in turn**:**

Research paradigm

The methodological approach has been to adopt a *postpositivist* research paradigm (Pickard, 2013). Postpositivism recognises that detection of social reality is subject to the frailty of human nature (as distinct from positivism which is bound more to laws governing the natural sciences). There is greater informality in the postpositivist approach which is in keeping with the focus on less quantifiable social issues relating to the STEM industry. Temptation to stray into the realms of conjecture and supposition are avoided. In particular, this meant that emotion and hyperbole which have clouded many STEM publishing issues – such as journal pricing, or the benefits of open access in STEM - have been isolated and then evaluated as part of critical analysis (such as with Monbiot's 'rant' (Montbiot, 2011), or Harnad's 'subversive proposal' (Harnad, 1994)). Evidence and statistics have been incorporated where possible to ensure that this thesis has solid foundation in fact and data.

Research Questions, derived from the research paradigm, are addressed at the outset of this thesis (section 2.4) and also answered in the conclusions (section 9.4). These questions translate the aims and objectives into specific issues which were investigated using the following methodology.

Research methodology

A mixed method research (MMR) approach was adopted during research phases, which resulted in an iterative build-up of an analysis of the STEM publishing industry. Both facts and data (quantitative) and also opinions and rationale (qualitative) were combined to reach balanced judgements on present and future scenarios. For example, the influence of professions on UK society (qualitative) was related to statistical data from the Higher Education Statistics Agency (HESA) on destinations of graduates and postgraduates (quantitative) to provide better evidence of demographic trends. Also, the indication that there is much latent demand for STEM material in non-academic centres (qualitative) was linked to data on turnaways from publisher web sites (quantitative). The correlation between quantitative and qualitative is not perfect, but this is more a reflection of the paucity of data produced by social statisticians rather than there being no relationship in reality.

Research methods

The strategic approach to this MPhil project was to base it on information and data resulting from original research, on work already done in this and related areas. Primary refereed journals were the main source for such published results.

However, as reported by Jisc and the British Library, there is an indication that doctoral students in the non-physical sciences rely on secondary sources (research journals, conference proceedings, books) and insufficiently on primary sources (social data, news, magazines and archived material). According to their report this challenges the concept of the doctorate programme being a 'research apprentice' (Jisc & BL, 2012). With this particular project the research draws both on informal, non-published, data and primary research sources (including Faxon Institute multi-client proprietary data and market consultancy data from Outsell) as well as formal published literature in research journals. It also includes original market research based on returns from semi-structured interviews both face-to-face and online made by the author in the course of this project. Case studies were undertaken (see Appendix 3) and other informal contacts pursued. Because the issues being dealt with are not rich in quantitative evidence – though data is included where available – 'exploration has become the main focus of this investigation, not testing or measuring' (Pickard, 2013). This thesis therefore offers a broad-based research approach to the topic – and addresses the points made for multi-source investigation referred to in the above Jisc/BL report (in "Researchers of Tomorrow").

As indicated above, an ongoing theme running through the project is that there is insufficient focus by either private or public organisations on providing consistent, quality and preferably linked-up statistical data, and this requires future inter-agency attention.

Research techniques

In Pickard's description, an '*analysis of existing, externally created material'* represents an important research technique, and this was employed. This is material which already exists, not created by the investigator, from which construction of an information/knowledge base collected from various sources has been undertaken. Selection of the sources and contacts was based on recommendations and feedback from individuals who have a recognised presence and reputation within the industry. Statistical data was also analysed, collected mainly from public sources. In addition, to complement the existing externally created material, interviews with approximately forty representatives from a cross section of the industry were undertaken. This provided new and original information - half being phone interviews and half being face-to-face meetings.

The kernel of the investigation relied on information in published literature. Firstly, an extensive literature review of formal refereed publications was made following the principles of desk research outlined by Denscombe (Denscombe, 2013) and Fink (Fink, 2014). Online bibliographic literature search covered terms related to both topics being researched (STEM dysfunctionality and UKWs). The provenance of the literature was important. Some of the formal literature relating to the STEM industry is distorted by the agenda and background of the respective authors or publishers. For example, open access as a preferred business model for STEM is viewed differently on issues such as support, value, relevance etc., depending on the politics, legacy and institutional affiliation of the source. Publication of research articles have been distorted (edited or rejected) because of conflicts between authors' and the publisher's agenda (as between Leicester university editors and Taylor and Francis publisher, see section 6.3.3). Such issues were taken into account and the content analysed accordingly.

Two approaches were taken in studying formal literature. Firstly, a search was made in the main online bibliographic data service (LISA) using search terms related to the topics. The results mainly described international analyses and the barriers confronting university-based end users in searching online. This was complemented with searching terms including knowledge workers, scholarly publishing, and scientific researchers against a global search engine (Google) – see following chapter on Literature Review for more details (Chapter 4.1). Relevant studies commissioned by Research Information Network (RIN), an independent research group, were also analysed. RIN had as its mission the exploration of developments in research communications during its five year existence. (RIN has since changed its governance and no longer produces nor publicly disseminates results of investigations in this area).

Secondly, there are informal 'publications' which report on trends facing scientific communication, and these are often more topical and timely in their content. They give a better insight into current and future trends facing STEM though they are not usually refereed nor part of scientific record or the 'minutes of science'. They are part of burgeoning social media. Whilst lacking in comprehensive and rigorous research practice, and relying frequently on anecdotes to support emotionally driven causes, they have relevance in indicating strategic trends which are frequently obscured in formal publications and data compilations.

Content analysis was also undertaken on monographs, general trade commentaries and reference works when these were considered relevant. It covered identification of themes through reading the original published sources (Denscombe, M., 2014, chapter 14). These works included views from writers such as Neilsen (2009), Monbiot (2011), Gowers (2014), Allington (2013), Murray Rust (2014), together with Carr (2010), Weinberger (2007), Tapscott (2008), Shirky (2008), Esposito (2013), amongst others (see section 4.1.2 in the Literature Review chapter).

Themes were extracted from analysing the full work rather than from an analysis of paratext (chapter headings, metadata) or coding material using text analysis tools (Neuendorf, 2002; White & Marsh, 2006; Krippendorf, 2013). The process involved identification of relevant qualitative concepts. Starting with one source and working through other sources, additional material for this thesis was identified in links cited within the source's text. As themes were added (or subtracted) these were incorporated within this project's body of research. They were checked to see that consistency was maintained. It was an iterative process, building on the corpus of published reports of repute, and critically evaluated throughout.

Over twenty face-to-face interviews were conducted. As the sensitive nature of the twin topics of this thesis occasionally generated strong emotions, the outcome of these interviews had to be related to the institutional agendas the individuals were protecting or promoting. These interviews were semi-structured in approach and varied in length - from a minimum of 15 minutes to over an hour - and took place in neutral locations or at the interviewees offices. The use of semi-structured interview techniques was to ensure that the necessary topics were covered whilst giving the interviewee the opportunity to raise any other relevant points they wished to contribute. (Pickard, chapter 7; Denscombe chapter 12). The details in the interview selected for discussion depended on the experience and background of the interviewee, though the questions all followed the main themes of the overall questionnaire. This involved addressing the twin aims of establishing the effectiveness of the current STEM information system and whether the potential for including the wider knowledge worker within the mainstream of research was included.

Selection of the contacts was based on networked feedback and cited references. (Pickard, A.J., 2013; Denscombe, M., 2010, chapter 12; Budd, 2006; Gorman & Clayton, 2005). This STEM industry sector is sufficiently compact such that those individuals who have useful and representative views to share tend to be visible, prominent and stand out. A selection of these gatekeepers or mavens, based in part by personal knowledge of the individuals involved, were contacted. None of the chosen contacts refused to be interviewed.

The resulting discourse analysis from these interviews involved either conversational analysis (CA) or critical discourse analysis (CDA) depending on how the interview progressed (Gale, 2010). According to Gale "The difference between CA and CDA is the extent to which analysts are justified in using information from outside a particular text" (Gale, 2010 p8). In this case it also included the experience, willingness to interact, personality and understanding of the issues involved as held by the interviewee. The intensity of their tone, emotions and facial expressions were therefore taken into account in assessing their comments and contributions. Some topics, such as 'open access in publishing', resulted in extreme reactions depending on its assumed impact on their business operations, and the physical manifestation (notably facial) of this reaction were taken into consideration when completing the discourse analysis.

Face-to-face meetings were also held with representatives from a cross section of the STEM industry.

Named individuals were chosen either because they were known to me personally as a result of work we have done jointly in the past in areas which relate to the topics of this thesis, or that they are recognised within the STEM industry as being thought leaders on developments in scientific communications. They were also referred to by other experts in the sector. In general there is confidence they would each give valuable insights despite, or because of, their different agendas on STEM and UKW issues.

Research instruments

In addition to the literature reviews and face-to-face meetings, two campaigns involving phone interviews were conducted to establish how researchers were adapting to the growth of digital STEM information services. The first was undertaken in October/November 2009, soon after commencement of this MPhil project. This was to help formulate the Research Questions derived from the research paradigm which became the basis for investigating the challenges facing the established STEM systems (see section 2.4 above). To quote from Gale (Gale, 2010, p 17) "For a systematic and more prolonged research project, it is important to have clear criteria consistent with the research question(s) posed. Without having clear research questions to frame the scope of your analysis, analysis can seem never-ending with no demarcated finish".

A semi-structured telephone interview approach was followed. 17 researchers at UK universities were contacted and written reports made of their answers to the questionnaire. Gale also comments (Gale, 2010, p 17) that "In doing discourse analysis, transcribing [thesis writing] is not a preliminary step to doing analysis, it is a significant element of analysis and practice for developing a critical and non-judgemental attitude". An example of one such transcription is given below as indicative of the reports written after each phone interview (see table 3.1).

Contact names were derived from a search of the researchers/senior lecturers listed on university web sites whose areas of research met the spread of subject areas included in this study. There were phone interviews with nine STEM respondents and eight from humanities and social sciences. Each phone conversation lasted from a minimum of 15 minutes to over half an hour.

The headline questions which were used for each contact included:

* Personal and demographic status of the respondent
* The split in their research or teaching activities
* Their use of research journals (and which ones)
* The online search techniques they employed
* Conferences and how important they were to their activities
* Social networking and collaboration which they undertook
* Use of datasets and alternative media

As an example of the recorded feedback from one such contact the following summary was made. Before undertaking the phone interviews agreement was given by each respondent to permit their views to be included in the thesis.

Table 3.1. Example of Phone Conversation with a cross section of 17 researchers in 2009.

Notes of telephone conversation with Dr John Lamb, Lecturer in Management at University of Aberdeen on 20th October, 2009.

Contact Details: Phone 01224 274362 (office); email j.d.lamb@abdn.ac.uk

Summary: Dr Lamb is an OR specialist rather than an Economist so was not aware of repec. However, he did make use of e-journals. He was also very critical of the power base which (STEM) publishers were adopting and purloining public-funded research results for their own gains.

Demographics: Dr Lamb's position is Lecturer at University of Aberdeen. His research and teaching area is Operations Research (OR). He had spent time working in industry (Pilkingtons). He also specialises in mathematical and statistical issues relating to management problems. He is male, and aged in the 30-40 age bracket.

Activities: Dr Lamb spent about 40% of his time on research, 40% on teaching and the rest on general administration. He is active in ensuring work is produced within the department to support RAE submission.

His research is funded by the university itself, not from external agencies (which has implications on his ability to pay for APC charges in submitting articles through the Gold open access route).

Dr Lamb tends to write one article a year. However, he expressed concern about the copyright stranglehold which publishers, notably large commercial publishers, have over the content of the published content. He was not aware of Creative Commons [see Acronyms in Appendix 2] and felt that it would be a good thing to have implemented – but it needs wider promotion. He basically felt it was 'bizarre' the power that publishers had over publicly funded articles. He would like 'to reduce the power of publishers'.

Creative Commons would help particularly with [distribution of] teaching materials. He was less concerned about the research area.

Journal Use: He makes extensive use of e-journals. This is frequently Elsevier titles which he knows are expensive. When he finds something he needs on ScienceDirect he prints off the article. Not every article but a fair number.

As far as print journals are concerned he only uses the one's he gets through membership of the OR society – he gets three of these including the *Journal of Operational Research*. Other titles he uses includes *Management Science and Networking* through which he also browses. He finds it easy to browse through these core print journals. Typically he looks for ways to browse for a particular issue in journals with large numbers of articles. He covers a wide range of journals.

He also thinks that ScienceDirect provides an easy browsing facility. He does this both from home and at the office. He has no problem with home access – he has set up a proxy server – though he is aware that others in his department do have problems accessing e-journals from home. He sometimes helps by setting up the authentication protocols for them.

In general he felt there were some good quality journals but equally there was a lot of bad and low quality titles, some of which skimped on the production process (camera-ready only). The latter were not doing scholarship any favours.

Searching: He also uses Web of Science to find suitable articles and then goes into ScienceDirect to print out the one's he wants.

Google is also used but less for scholarly material. These can include references to relevant conferences. GoogleScholar is also used.

Repec – he was not aware this existed. But repec is mainly for mainstream Economists and his interests are in Operational Research.

Institutional Repositories. He does access these if he is aware of an author whose article he wants and needs the information quickly. He will also email the author directly. This will enable him to pick up the latest information.

Conferences: These can be very important in his area. They are often part of the informal communication system, but they are valuable in letting people know who is doing what and whether they are succeeding. These are accessed either from IRs or from the author's web site.

Social Networking/Collaboration: Blogs, wikis, etc, are not very important in his area. However, email exchange can be useful. They can become the channel for discussion about a particular research project. Moderated listservs were not mentioned.

Data and Datasets: These are not important at all. There are very few large useful datasets. The smaller ones – 10 mgb or so – can be handled on one's own machine. They do not impact on the research article content.

Alternative Media: In line with his concern about IPR he would like to see more alternative media becoming available. He referred to a mathematical journal which was only available online which he felt was a step in this direction.

A second phone study was undertaken in the Summer of 2011 to make sure that the thesis was tackling issues fundamental to the health of the STEM paradigm, and was a longitudinal study in the sense of seeing how a similar cadre of users (though not identical due to career mobility issues within academia) had changed their opinions over a two-year period.

The disciplines covered in this second phone questionnaire study were targeted at the topic and aims of the thesis (library/information science; sociology of science; business and related areas). A slightly broader subject scope was also included. The spread of the 21 interviewees by subject specialism in this second study included:

Table 3.2. Data on Disciplines of Interviewees

Country	*LIS*	*Business*	*Sociology/soc*	*Others*
United Kingdom	5	5	3	2
United States	2	2	-	1
Others	1	-	-	-

As with the first study, the phone discussions lasted between 15 and 40 minutes. Both sets of responses expressed concerns about the current effectiveness of STEM communications (see section 5.14.2 in the Unaffiliated Knowledge Worker chapter).

Semi-structured interviews were undertaken with the twenty-one academics identified in the above table (3.2). With the semi-structured interviews, the questions asked were predetermined but allowed for subsequent non-scripted questions to be asked depending on the answers already given. Responses to each question were then compared with related responses from other interviews/contacts. It is a less structured approach than that used in quantitative methodology but gives full reign to allowing subjective feedback from those with expertise in niche areas to be included. A summary of results is included in sections 5.14.2 and 5.14.3.

Questions asked of the contacts in this second phone interview session were:

1. Introductions, description of aims and position/activity of the interviewee. (This also included making them aware of the UCL Research Ethics policy, and gaining their consent to be interviewed).
2. Are they part of an online STEM information community – either active or passive? If so, which?
3. Are there any communities of which the researcher is aware that they have decided not to take part in – and why? Is there a demographic aspect to being part of an online community/portal or hub? Is it just for the young?
4. A leading distraction claimed for Internet-based services is that they create excessive 'white noise'. Is this an important issue?
5. Open Access (OA) claims to offer advantages which obviate the need for formal published articles. Is this the case for you?

6. Social media based information services offer the opportunity to break away from 'elitist' and closed STEM publishing system (serving research libraries), and open up discussion to a global, wider community. How realistic is this?
7. Is there a role for the traditional publisher in creating and maintaining online communities? Or are learned societies better equipped?
8. Is there an acceptable business model which supports online activity?
9. Is there anything else which is relevant to the future progression of publishing within scholarly discourse?

Specific attention was focused on their concerns about existing publishing systems, and their use of social media, communities and open access routes in accessing research outputs. This study identified a distinction between the traditionalists and innovative researchers, with the split being approximately 50:50 in this study (see also Case Study described in Appendix 3b).

Also included in this assessment were economic and business models appropriate in an information economy which is moving from a print to digital delivery. A SWOT (strengths/weaknesses/opportunities/threats) analysis of the main stakeholders in the scientific information sector was made and summarised in the Discussions chapter (see section 8.4).

In addition, email communication was established with several individuals who represent sectors of STEM which are important to the industry's future development. They were selected because I knew them personally, because I was aware they had something useful to say, and because they were unavailable for face-to-face meetings. They ranged from the chief executive of one of the big five STEM publishing houses (Springer Nature, based in Heidelberg, Germany); the secretary general of a leading STEM publishing association (International Association of STM Publishers, Oxford-based); practitioners within learned societies, and consultants to the STEM publishing industry.

The structure of the email questionnaire depended on the position, experience and personal knowledge about the individual. Due to the nature of the (email) channel specific issues rather than exploratory discussions were pursued. The specific issue in each case was dictated by the knowledge base of the contact, and that the issue fitted in with the scope and aims of this project. Each contact was emailed at least once; in some cases it resulted in an exchange of emails, and in one case to a transatlantic Skype online discussion.

Finally, quantitative data was sourced from the main public statistical sources in the UK, as well as international agencies. In particular the UK academic sources were the Higher Education Statistics Agency (HESA, 2010; HESA, 2014), the Office of National Statistics (ONS, 2011; ONS, 2014), the Department for Business, Innovation Skills (UKDBIS, 2009; UKDBIS, 2011), Undergraduate Courses at Universities and Colleges (UCAS). Global data came from the US National Science Board (NSF, 2010; NSF, 2014), Unesco (Unesco, 2010; Unesco, 2015), OECD (OECD, 2008; OECD, 2015) and the European Commission's Eurostat service (Eurostat, 2007).

In each case the data compilations from each of the above agencies was analysed in terms of their relevance to the STEM sector and whether they shed any light on UKW information needs.

The above activities led to a synthesis of ideas, opinions and experiences. This formed the evidence base from which the *Research Questions* – as formulated in the early phase of the research project – were revisited in the summary section of this thesis (section 9.3).

3.3. Alternative Methodology

There are other methodologies which exist and were incorporated within several studies analysed during the course of this MPhil project. Though none were primary sources of research in this study by this author they should nevertheless be considered appropriate in future extensions of an in-depth investigation into STEM and UKW issues.

Literature referred to in this project often included attempts by third parties to make use of alternative methodologies in their work. Therefore, some of these alternative methods are included in this thesis, but it is through second hand absorption of a third party's results. They are derived results rather than original to this thesis.

The alternative methodologies include:

3.3.1. User studies

Studies have been undertaken on researchers using both print and electronic methods for canvassing opinion and collecting results (such as Ware, 2009b). Whilst these are valuable they suffer from several weaknesses, including small sample sizes – compared with the universe of researchers – and the low response rates achieved (with 3-5% being typical). Also the questions asked of researchers require subjective assessments in many cases, and spur of the moment responses may not reflect the actual event. However, the use of critical incidence technique (focusing on the latest use data) and tripartite research (combining several related study techniques) reduce such inaccuracies. King and Tenopir have been pioneers in such user studies on researchers in the US (Tenopir, King et al, 2009).

Small sample sizes and requesting opinions about past events which rely on memory of the respondent makes user studies of questionable reliability. Added to which they are historically-focused, and as will be pointed out in later sections of this thesis, there are significant changes in user behaviour which is being dictated by a move from a print to a digital paradigm. Retrospective-looking user studies would give little guidance where such volatility in user behaviour would lead to - it focuses on the impressions of digital immigrants (old school) and not digital natives (new school).

What may be useful for this project would be for future research be undertaken into ‘virtual communities’ as these are on the digital fringes of STEM communications, and netnography would be the appropriate methodology (Pickard, 2013 xxi) with which to canvass user opinions.

3.3.2. Log analyses

This technique overcomes the low sampling problems of user studies. The pioneers in this area are LANL (Los Alamos National Laboratory) in the USA and CIBER in the UK. CIBER in particular has focused on analysing log data from the STEM research community (Nicholas, 2010b).

Both LANL and the CIBER teams recognised that researchers and users leave a ‘digital footprint’ or ‘digital exhaust trail’ in their wake when searching for or looking at information online (Bollen J et al, 2005. Nicholas, 2010b). This digital trail provides a more accurate picture of usage behaviour than that obtained from small samples of questionnaire responses. Every click on the keyboard can be measured and used to interpret actual activity. It gives robust and abundant data of actions actually taken, and does not rely on impressions or distant memory, nor is it dependent on aggregating from small samples to reach speculative conclusions.

CIBER has produced several reports based on the digital trail left by the STEM digital natives, highlighting the actions of the Google Generation. Information-seeking in this group was seen to be fast, furious, abbreviated, and promiscuous. Bouncing and skittering were the preferred forms of behaviour; viewing was preferred to reading; few people undertook advanced searching; and everyone used Google. Follow-up work showed it was not just the Google Generation, but also ‘virtual scholars’ that were behaving in ways not quite how librarians and publishers had envisaged when designing their websites and databases (Rowlands et al, 2008; Nicholas, 2010a).

3.3.3. In-house market intelligence

Publishers and intermediaries have access to a large dataset of market information resulting from their on-going commercial operations. However, it is indicative of corporate myopia - by ignoring available market intelligence information such in-house data not been mined as a strategic resource. From CIBER UK’s home page it appears “In some cases half of all attempts to access full-text content [on a commercial publisher’s web site] are turned away”. (During a 6 month period, one commercial journal publisher had 14,082,824 ‘turnaways’ from their site, 84% of which did not have any subscription entitlement to access to the content – source, anonymous publisher whose proprietary interests are being respected).

This traffic invites questions about who are being denied access to published material both on an individual publisher basis as well as industry-wide. Turnaways represent a market need which indicates lack of fulfilment – more than that, it exposes publishers’ focus on low hanging fruits of the STEM information business, and inadequate sophistication in researching the broader context within which STEM could operate. UKWs would be part of the turnaway analysis.

3.3.4. Delphic and other market forecasts

The impression is that the STEM industry has been protective of a regime which ensures that quality (refereeing) remains paramount, and that the subscription/licence continues as the preferred business model for sustaining its operations. In a static world this is understandable.

However, what is lacking is a crystal ball for gazing into the future into what form Science and its support activities such as STEM, will take. Delphic studies by knowledgeable experts on the industry, and their adopting techniques for future forecasting in a social sector which is in turmoil, is a gap in the current approach. Bringing together the 'perfect storm' factors (see section 5.9 on Environmental Changes affecting UKWs, and section 6.4 on Environmental Change impacting on the STEM industry) – instead of focusing on specific issues such as 'open access', industry 'dysfunctionality', subject differences, and search enhancements – would provide a new direction for the STEM industry. It would also enable the wider needs of a disparate UKW audience to be addressed and included.

The fear is that it is impossible to forecast the technology infrastructure which will exist in five years time. During the past twenty years we have seen dramatic developments which no one would have been able to forecast at the time and yet which have changed society. The arrival of the PC; the emergence of the Internet; smartphones; social media - these and many others have radically transformed society during a period when STEM has changed very little.

Crystal ball gazing has its limitations but also has the potential benefit to create a mindset which would be receptive to incorporating new approaches and paradigms for STEM. Exploring new horizons through Delphic approaches would act as a counterweight to the current navel gazing which is described in literature-based studies.

The description of the future given by Professor Jeffrey (Jeffrey, 2012) is indicative of the type of input which could feed into refined strategic analyses of the future for STEM (see chapter 6.6).

3.4. Research Ethics

The provenance of the original research information collected for this thesis was dependent not only on the above methodology being adhered to but also that the external providers of information agreed to an ethics declaration.

All contacts were made aware of the scope of the project and agreed to participate and allow their views to be incorporated into the thesis. The interviews abided by the University College London's Statement on Research Integrity (latest edition published in May 2015) as related to Universities UK's Concordat to Support Research Integrity (2012) and UCL's current Code of Conduct for Research. This includes the Code's commitments in the areas of honesty, rigour, transparency and open communication, care and respect. Transparency and open communications have been particularly relevant for this thesis, though all part of the Code's features have been adhered to. (See https//www.ucl.ac.uk/research/integrity/research-ethics).

All contacts gave their agreement to allow their input to be included in the thesis.

3.5. Constraints and limitations

A self-imposed limitation was to focus on challenges facing, specifically, the United Kingdom in coming to terms with STEM's functionality and UKW disenfranchisement. This was to highlight the problems which emerge as a result of combined demographic, educational and funding issues in the UK; other countries operate under different structures and constraints and would need separate study.

The early intention was to get support for a questionnaire mailing from a number of learned societies to investigate how UKW professionals within their membership kept up-to-date with scientific developments. This aspect of the project proved difficult because of lack of funding opportunities (to finance extensive mailing and data analysis) and an assumption by several learned society publishers that ‘they knew their market’s needs’. (This came as direct feedback from the interviewees among the societies, see chapter 7 on UK Learned Societies).

Another limitation was that the Delphic approach required collaboration from an international group of experts, whose busy schedules could be a problem. The attached thesis can be used as a baseline report for a future professional, dedicated and knowledgeable group of experts to focus on giving realistic forecasts on trends facing the STEM industry.

In the meantime, the feedback from the interviews, the statistical analysis, and the literature review provided triangulation of methods and sufficient evidence to indicate that scientific journal publishing is at a crossroads, and that there is also the need to address the scientific information habits and needs of unaffiliated knowledge workers.

4. LITERATURE REVIEW AND ANALYSIS

The approach taken on literature review and analysis has been to combine assessments of both formal, refereed publications relating to STEM and UKWs and also informal, social networking commentaries on these topics as well as data collection and analysis.

This triple approach is necessary because of the general lack of credible published information in traditional learned journals alone about STEM and UKWs. Topical commentaries and valuable strategic insights are just as often to be found in the informal online literature which gives them a role in providing strategic perspective about the subjects of this thesis.

4.1. LITERATURE REVIEW

Based on findings from online searches of the formal literature, through bibliographic database and general search engine interrogation, the following were identified:

4.1.1. Online Bibliographic Search of Formal Literature

4.1.1.1. Findings related to problems of access within academia itself

The Research Information Network (RIN) summarised several studies which it had commissioned into access difficulties facing STEM academics in a report published in December 2009 entitled "Overcoming barriers: access to research information" (RIN, 2009). RIN used a web-based survey to assess the nature and scale of difficulties encountered. The sample consisted of researchers at Scottish universities. Most of the problems revolved around access to e-journals. It became apparent that even among the 'affiliated' (university-based) target groups there are problems in accessing scientific literature. With regard to the impact on researchers' work, over 80% of the academic respondents said that access problems 'did have an impact' on their research, and nearly a fifth said that the impact was 'significant'. The proportions of those who felt the impact was having a 'significant' impact were higher at non-research intensive universities.

This is important given assumptions that it is only organisations outside academia that suffer from the current process of STEM information dissemination. It suggests that there is unsatisfied demand even within the 'privileged' sectors of the science community for easy access to STEM. The implication this has on the progress for a science-led society is significant.

Another RIN funded study (Rightscom, 2009) used an online survey of researchers, individual interviews and focus groups to collect information from academic researchers in a number of disciplines across the UK about non-cost barriers to accessing scientific resources. Results showed that over half the respondents had experienced problems getting information they needed for their research.

RIN, together with Jisc and the Publishing Research Consortium, commissioned follow-up studies to make recommendations for reducing barriers to access investigate. The final report of this series was completed in December 2011 (Rowlands and Nicholas, 2011) and is described in chapter 5.13.1.4. It reinforces the concerns made in the earlier RIN-funded studies.

4.1.1.2. International studies

An international perspective was provided in a study by Dilek-Kayaoglu, (Dilek-Kayaoglu, 2008). Istanbul University faculty were surveyed to examine their use of electronic journals. The main problem here was a lack of subscriptions to required material, which was mentioned by 75% of respondents.

Scientific information access has also been looked at in other countries from the perspective of the usability of digital interfaces. For example, Ramlogan and Tedd (Ramlogan, 2006) explored the use and non-use of selected, subscribed electronic information services (EIS) among undergraduates at the University of the West Indies, in Trinidad and Tobago. Results showed that 64.1% of non-users (which accounted for 54% of respondents) indicated that lack of awareness was the primary reason for non-use. These studies highlight that developing countries face significant problems in accessing the world's STEM literature.

4.1.1.3. Findings related to problems of access between academic centres

In a report for the Research Information Network, RIN, in April 2007, Key Perspectives Ltd (Swan & Brown, 2007) explored the availability of content for researchers within UK institutions and libraries. Usage was dependent on two factors: (a) the license terms the institution negotiates for its e-resources, and (b) the level of IT facilities available to external users from within the library.

Availability of IT support "depends on cooperation between computing service departments which may not place high priority on the needs of external researchers" (Swan & Brown, 2007). In most cases, libraries did not allow access to electronic resources by non-members due to licensing restrictions set by publishers, and a SCONUL Access card offered no tangible benefits. (SCONUL Access is a scheme which allows many UK university library users to borrow or use books and journals at other libraries which belong to the scheme).

Almost all UK universities have bought into the SCONUL Access scheme, the exceptions being Oxford and Cambridge and a few specialist institutions. Nevertheless, more than half of respondents (56%) did not have a SCONUL access card (Outsell, 2009b), even though they were from eligible institutions. This is particularly true of researchers in science and engineering and those from Russell Group institutions.

In another RIN study undertaken in the UK by the consultancy company Outsell Inc, the focus was also on the publishing, information and education industries and how such institutions are managing the provision of access to information resources for researchers who are not members of the institution – though still ostensibly from academic/research centres and therefore 'affiliated' researchers (Outsell, 2009b). This study found that researchers make use of resources beyond their own institution to a considerable extent, and in general do not encounter significant obstacles accessing *print* resources. However, this is not true of *digital* resources, access to which is more restricted as a result of the local licensing contract.

4.1.1.4. Access by individuals from non-core academic centres

Difficulties facing access to scientific information has also been considered from the perspective of 'knowledge transfer'. Dobbins and colleagues (Dobbins et al,

2007) assessed the need for research-based information by decision-makers working in community-based organisations. The study focused on health and health information professionals. The problems identified provide a contrast to those outlined above in that they explored the context within which information is required rather than just accessing issues. For example, one of the barriers was lack of available time to search for literature. Limited critical appraisal skills needed to evaluate literature, excessive material to review (which may result in overlooking quality literature), work environments that do not support research knowledge transfer, and limited resources were also noted.

Rosenbaum and colleagues (Rosenbaum et al, 2008) explored user experience of health professionals trying to find evidence in *The Cochrane Library*. Researchers carried out 32 one-hour usability tests on participants from Norway and the UK. They were asked to browse freely and to perform individual tasks while 'thinking aloud'. The first task for participants was to find the website. Thirteen of 32 'testers' failed to find the Cochrane service online, even though 11 claimed to have used it before.

4.1.1.5. Search aids

Muramatsu (2001) reports that users generally have difficulty using search engines to undertake queries using default search mechanisms, such as automatic Boolean operators, stop words, truncation and term order sensitivity. For those unfamiliar with bibliographic databases (and past research suggests that even those in higher education tend to prefer services such as Google Scholar or other general purpose search services) this poses a challenge (Rowlands and Nicholas, 2011).

On the other hand, the information-seeker may be searching for 'a document that is easy to understand' (Crystal & Greenberg, 2006: p1371) and may benefit from a search on Google. In a standard bibliographic abstract and index (A&I) database, 'there may be no query option for "easy to understand documents"'.

4.1.1.6. Authors' rights

A related issue looked at perceived and actual challenges facing authors in the publication of their research results. It was investigated by Morris on behalf of Publishing Research Consortium. In PRC Summary Paper 5 entitled 'Journal

Authors' Rights: perception and reality' (Morris, 2009), Morris examined what is permitted by publishers' author agreements, and what authors think they are allowed to do. The two do not always coincide. For example, authors significantly overestimate the extent to which they may self-archive the published PDF version.

However, according to Cox (Cox and Cox, 2008) publishers are introducing more lenient licensing terms for digital content, allowing use in some instances of author's material within VLEs (virtual learning environments) and re-purposing to create learning objects. Also, fewer publishers now require authors to transfer copyright to the publisher and instead accept having a licence to publish. Whilst larger publishers are adopting a more relaxed attitude to posting pre-prints on local institutional repositories, they have imposed more stringent time-based embargoes on making the accepted (published) version more widely available.

Prolific commentators on users and authors of scientific literature over the past decades have been Professors King, University of North Carolina, and Tenopir, University of Tennessee (King & Tenopir, 2011; 2009 and Tenopir & King, 2000). From his original work on 'Statistical Indicators of scientific and technical communication' for the National Science Foundation in 1960, King has built an expertise in quantifying the size and growth of published STEM material and the way it has been used. Tenopir has written extensively in the 1990s and 2000's on the usage patterns in individual disciplines/professions such as engineers, paediatricians and academics as they migrate from print to online access of scientific material (Tenopir, King, et al, 2007; Tenopir, 2004). Most of these studies have focused on how US researchers have used formal research literature; there is limited evidence on how UKWs respond to STEM in their reports. The results are also limited to past and present usage practices, which give no indication of future requirements.

Another major study on users and authors comes from the Center for Studies in Higher Education (CSHE, 2011), University of California, Berkeley. With funding from the Andrew W. Mellon Foundation, CSHE conducted research to understand the needs of faculty for both scientific communication as well as archival publication. These studies describe a powerful conservatism in the way authors and users have embraced current STEM publishing systems, and are more cautious on switching to alternative, informal publishing services.

4.1.1.7. Social networking

In practice the changing STEM publishing scene has led to social media and social networking services eating into the traditional book/journal markets in several scholarly subject areas. Pundits such as Carr and Tapscott (Carr, 2008; 2010; Tapscott, 1998) have written extensively on the social psyche and how digitisation and the Internet are changing the way people, in particular researchers, read and gain access to research output. This change in behaviour is reinforced by a number of social concepts – 'the long tail' (Anderson, 2004; 2009a) is particularly important, suggesting that digitisation changes the business model by supporting the needs of the peripheral markets (such as UKWs) over that of the core (academic) audience. Other related concepts include 'the tipping point' (Gladwell, 2000), the 'wisdom of the crowd' (Surowiecki, 2004) and 'here comes everybody' (Shirky, 2008) as a reflection of increasing democracy in STEM. These concepts are explored in more detail in the sections describing sociological/demographic impacts on researchers and UKWs (see sections 5.9 and 6.4).

4.1.1.8. Typology of UKWs

Few studies have looked at the different types of UKWs which could be served by a more open and democratic information system. Early investigation of academic researcher typology was undertaken by the Faxon Institute (Faxon Institute, 1992) as part of a multi-client study (grey literature), and also by a HEFCE funded report on 'SuperJournals' (Pullinger & Baldwin, 2002). Though providing interesting insight into different mindsets of researchers, neither of these studies extended their investigations into the wider markets of the professions, SMEs and citizen scientists (see section 5.13.1).

The impact of a generational change in the way individuals have adapted to the new digital services was first described by CIBER (Rowlands et al, 2010) in their report on the 'Google generation'. It has been followed by many others who have highlighted the 'digital natives' and 'virtual scholars' and how they differ from silver surfers and the rest of society in using digital information (see section 5.11).

Results from formal literature review

A key result of the formal literature review is that the body of published information on which to build effective policies and strategies to address the challenges facing STEM industry and UKWs is lacking. More specific research into the underlying issues particularly relating to the strategic health of the STEM sector as currently configured is necessary. Also, user studies of unaffiliated knowledge workers are required.

Specific difficulties identified from the online search on literature relating to STEM and UKW are summarised as follows:

- Inaccessibility of material within libraries of which researchers are members
- Inadequate library visitor rights: including restricted access to digital material
- Technical and resource issues: slow connections; insufficient hardware (mainly in overseas third world territories)
- Knowledge of resources and their coverage: knowing which databases or services to use
- Search inadequacies: both on the part of the users - in failing to exploit advanced search facilities, for example - and systems, where too rigid an interpretation of search terms preclude effective information retrieval
- Contextual, wider barriers such as time constraints, information overload and work environments not conducive to literature searching

4.1.2. Online Search of Informal Literature

Social media and social networks have become platforms upon which questions about the state of STEM publishing are being openly and energetically discussed. They provide a basis for questioning whether the traditional STEM publishing system is fit for purpose, whether it is dysfunctional and also whether failure to meet UKW information needs is one of the casualties.

There is evidence that innovative communication services are emerging in response to concerns from researchers themselves rather than publishers and librarians (*Mendeley,* *ResearchGate, Knovel*). This includes new reading patterns being adopted by researchers at the coalface as described by Jeffrey (2012) and Murray Rust (2014).

During the past few years there have been a number of prominent industry-watchers who have given their views on the current STEM scene. They have taken the moral high ground, looking at the political, social and economic consequences to society resulting from continuation with the present publication system. They have generally been critical of the *status quo*.

Their commentaries have been subject to critical analysis given that they are based on opinions by individuals, and countervailing considerations need to be taken into account. The format for literature review therefore involves a lengthier analysis of each commentary rather than the synopses given earlier in the formal literature of often small scale results of specific aspects of STEM information dissemination.

This is a sample of the more eloquent and credible. It avoids comments from those who have been too partial, blinkered or emotional in their commentaries. Nevertheless, the following have still made powerful complaints – they expose tensions within the STEM sector in particular (see section 6.3) which is an important cornerstone to this thesis.

For the purposes of this analysis of the social media it would be useful to see whether the needs of UKWs are also addressed in their criticisms. So far there are few indications that critics have taken UKW needs into account. The needs of UKWs rarely appear as front-line issues, instead the focus is invariably about the iniquities of the existing players - notably large commercial journal publishers - and how STEM publishing overall is no longer fit for purpose in serving academia.

Leading writers about the STEM scene include:

4.1.2.1. Michael Nielsen, author

"Is scientific publishing about to be disrupted?" was a question raised by Nielsen in a blog on June 29th 2009 about the future of STEM publishing (Neilsen, 2009). His premise was that there are a number of industries which have been sidelined because they were structurally unable to cope with the new economics facing their particular industry sectors. He cited the print newspaper industry, music and mini computers as examples. The leaders of these industries were not, he claims, either stupid or malevolent – it is because the underlying structure of their industry, primarily their scale of operations, was unsuitable for new and emerging market conditions. The immune systems of these industries were protective of an established organisational structure and this ran counter to the openness and demands for free information which has emerged on the back of the technological/Internet revolution.

Nielsen asserted that STEM publishing is about to face the same disruption. He claimed that large publishing houses will need to compete with new companies which focus on meeting new digital preferences in the information industry. In effect he claims the large traditional publishers will have to traverse 'the valley of death' to survive (see section 5.14.4.4).

He pointed out that senior positions in the larger scientific publishing houses are rarely held by technologists. Most publishing management have strong business or editorial skills. He claimed that in ten to twenty years' time "scientific publishers will be technology companies. Their foundation will be technological innovation and most key decision-makers will be people with deep technological expertise". He suggests there is a flourishing ecosystem of start-ups in scientific publishing that experiment with new ways of communicating research, radically different in approach from journals. They are better prepared to cope with a change in techno-market conditions, and emerging democratic trends, than current STEM publishers wedded to elitist principles focused on serving academia (Neilsen, 2009).

Lessons can be learned from new giants that have emerged on the information scene (Google, *FaceBook*, Microsoft, Apple). They have been successful in a free and open industry sector. By reaching out to wider global communities and taking smaller individual payments for services provided, revenues flow in. Many smaller payments from a much larger audience is a healthier business proposition than relying on a few customers who complain about high subscription prices (see Dysfunctional STEM, chapter 6.3).

As identified by Nielsen, the immune system for scientific communication is strong in protecting traditional publishing formats and systems. The question is whether their existing scale of operations will be sufficient to sustain them given the economic, financial, social and technological challenges they face (as described in chapters 5.9 and 6.4).

4.1.2.2. George Monbiot, the Guardian

Another strong indictment of STEM publishing was made a couple of years later by the journalist Monbiot, in an article in *The Guardian* on 29th August, 2011 (Monbiot, 2011). He claimed it is not possible to recognise the picture of a flexible, rapidly reactive large commercial publisher rushing to embrace the new millennium. There has been, according to Monbiot, lack of leadership from publishers in switching from the traditional subscription model to new untested ones. This is because the commercial risks involved are unknown and unpalatable. Why throw away a regular and stable almost 40% gross margin on a serial subscription service in favour of something a lot less? (Monbiot, 2011).

This has led to many seeing the scientific publishing industry as being greedy and non-responsive to new market needs. According to Monbiot, "who are the most ruthless capitalists in the western world? Whose monopolistic practices make Walmart look like a corner shop and Rupert Murdoch a socialist?" His vote goes not to the banks, the oil companies or the health insurers, but instead to STEM publishers. "Of all corporate scams, the racket they run is most urgently in need of referral to the competition authorities".

"Without [access to] current knowledge, we cannot make coherent democratic decisions". But according to Monbiot, "the publishers have slapped a padlock and a 'keep out' sign on the gates". Downloading a single article published in one of Elsevier's journals costs $31.50. Springer charges €34.95, Wiley-Blackwell, $42. And the journals (publishers) retain perpetual copyright. "If the researcher wants to look at a printed letter from 1981 that can cost a further $31.50".

Though it is possible to go to the local research library, they have been hit by budgetary constraints (see section 6.3). "The average cost of an annual subscription to a chemistry journal is $3,792. .... The most expensive primary research journal is Elsevier's Biochimica et Biophysica Acta at $20,930" - the price each year of a family car. Though academic libraries cut subscriptions to make ends meet, journals still consume 65% of their collections budgets, which means they have had to reduce the number of books they buy, and budgetary pressures are being exerted on staffing and facilities including storage.

In addition, not everyone is able to make use of the nearby university research library. Unless one is affiliated with the library in an acceptable way – as a student or member of staff – the terms of the licensing agreement between publisher and research library is such that that the unaffiliated would be turned away from accessing online information published by STEM publishers.

Monbiot laments that STEM publishers get their articles, their peer reviewing (vetting by other researchers) and even much of their editing is done for free. Also, the material they publish was commissioned and funded by the tax-paying public, through government research grants and academic stipends. But to see it, the general public, knowledge workers and much of academia must pay for it again.

Publishers claim that they have to make these charges because of costs of production and distribution for a limited (research library) market, and that they add value because they "develop journal brands and maintain and improve the digital infrastructure which has revolutionised scientific communication in the past 15 years". However, an analysis by Deutsche Bank reached different conclusions. "We believe the publisher adds relatively little value to the publishing process … if the process really was as complex, costly and value-added as the publishers protest that it is, 40% margins wouldn't be available" (Monbiot, 2011). Far from assisting the dissemination of research, the big publishers impede it, as their long turnaround times can delay the release of findings by a year or more.

However bad the situation is for academics and researchers, it is far worse for the laity. Independent researchers who try to inform themselves about important scientific issues have to pay thousands of pounds. It appears to contravene the universal declaration of human rights, which says that "everyone has the right freely to … share in scientific advancement and its benefits". In the USA, in support of open access, Dr Stuart Schieber, Director of the Office for Scientific Communication at Harvard University, has pointed to Thomas Jefferson's claim "the most important bill in our whole US code is that for the diffusion of knowledge among the people." (Harvard University, 2012). These are important mantras around which this thesis is built. Empower the many with the results of society's scientific progress (and not keep it locked away for the wealthier academic/industrial institutions) offers attractive social benefits for a democratised STEM information system.

It was inevitable that Monbiot's criticism of the scientific publishing industry would be challenged. In one of the leading publisher journals, *The Scholarly Kitchen*, on 1 September 2011, Anderson in the U.S. claimed that the arguments put forward by Monbiot were 'uninformed, unhinged and unfair – the Monbiot rant' (Anderson K, 2011). Others who are closer to the publishing industry feel that Monbiot has a jaundiced view of the commercial STEM publishers and is extreme in his arguments. However, the Monbiot 'rant' does provide an inventory of some of the leading issues being debated at present about STEM.

4.1.2.3. Sir William Timothy Gowers, Cambridge University

From a different perspective, a reputable scientist who supports the sentiments expressed by Monbiot is the Cambridge Professor, Sir Timothy Gowers. In his case he saw Elsevier as the villain in draining profits from the science budget into the hands of financiers. In 2012 Gowers wrote an article for *The Sunday Times* which ignited a campaign for authors and readers to boycott Elsevier publications (Gowers, 2012).

Such a campaign from within the research community is not new. There was an earlier outcry against commercial journal publishers led by Dr Michael Eisen in the USA which led to the formation of the Public Library of Science (PLoS). 34,000 signatories were collected in Eisen's campaign in the US to complain about STEM publishing.

Within weeks of the UK-based Gowers appeal, 9,000 scientists globally had signed up to the petition pledging to refrain from editing, publishing or sponsoring articles in any of Elsevier's over 2,000 journal titles. The stimulus for the campaign from what *The Sunday Times* referred to as this 'thoughtful academic' was partly the high profits generated by Elsevier, and partly from the effects which the economic downturn was having on science budgets, including libraries (Gowers, 2012).

Gowers claimed that publishers such as Elsevier were ruthless in cutting off journal supplies to the captive market they serve – research libraries. In particular, there were barriers stopping attempts to negotiate better deals on the package of journals within their portfolio of 'big deals'. This included preventing librarians discussing and comparing the financial terms each library had negotiated with the publisher under pain of legal sanctions being imposed.

However, according to Gowers, the Internet is undermining the stranglehold which journal publishing has had in that new forms of communication are being created, relegating the published journal article to that of being a version of record (VoR). "Interesting research gets disseminated long before it gets published in official journals so the only real function that journals are performing is the validation of papers". Given that published articles are no longer a communicator of the progress of science it seemed, to Gowers, a travesty that Elsevier should have earned £768 million for its private investors in 2011 from its archival activities in the public scientific arena.

Whilst authors were distanced from the commercial activities of the publishing giants, and readers were separated from the purchasing decision by the research library and their collection development policies, the *status quo* would be maintained. Gowers' call for action was an attempt to highlight dysfunctionality within the industry. The conflict was between freedom and openness of science in the Internet clashing with the profitability targets set by the owners of publishing conglomerates.

He invited mathematicians from Cambridge University to give their views on the importance or otherwise of continued access to Elsevier journals as part of their research efforts. He concluded "most people would not be inconvenienced if they had to do without Elsevier's products and services, and a large majority were willing to risk doing without them if that would strengthen the bargaining position of those who negotiate with Elsevier."

Although complaining about the actions of the market leader in itself is not an indicator of the dysfunctionality of the publishing system, it does suggest that there may be other better ways for STEM in future.

4.1.2.4. Andrew Brown, the Guardian

In the February 5th, 2009 issue of *The Guardian*, Andrew Brown offered another critique of the STEM publishing system. He also claimed that scientific journals were a notorious racket. This was because they are essential tools for the researchers that use them and publishers could charge pretty much what they liked.

Brown pointed out that the government paid universities to conduct research for the public benefit. The authors of the research results are paid nothing; the peer review is done for free, by academics employed and paid for by universities. The results are then sold back to the universities who supported the research in the first place. “This is poor value for governments. It is also difficult for those outside a university who may want to learn, and that's a situation the web has made more tantalising”. Almost all journals are indexed and references to them can be found on Google Scholar, PubMed Central and other leading comprehensive online data sources. “So the truth is out there. But it will cost you” to get access to the full report (Brown A, 2009).

One answer, he claimed, was to promote free scientific publishing, and also free access to the immense quantities of data that lie behind most published papers.

4.1.2.5. Daniel Allington, Open University

Daniel Allington, professor of sociology at the Open University, wrote a blog about the role of such free or open access in the scholarly communication process (Allington, 2013). Though he initially felt that Green Open Access was an improvement over the traditional toll-based or subscription-based publication system, he subsequently felt that the wrong questions were being asked. Open Access was being proposed as a solution to a range of problems which had little to do with one another, and very little to do with creating an effective scholarly communication process.

Support for the Green Open Access movement (which involves depositing research outputs in one’s local institutional depository and the latter then making them available free of charge to anyone) ignores the fact that there is a need to fund institutional repositories. This means that the financial pain is switched from one institutional account to another. The overall costs of scientific publications would remain the same for both traditional and Open Access publishing as long as there is a need for quality control over what is published.

Allington makes reference to an alternative open access system which would be an improvement if the main goal is to improve the reach of published material to UKWs and knowledge workers generally. This alternative would be an insistence by funding agencies to include 'non technical summaries' written by the recipients of research grants in support of their research application, and to have these summaries together with the summary of the final research outcome posted on the funding agencies' web sites which could be freely accessed. Though this does exist in many instances it is not heavily used. This is probably a failure in promoting the system rather than any weakness in the concept. It is one which has been proposed by Esposito as part of a new tertiary publication service from the publishing industry (see Nautilus by Esposito, 2007 and section 6.6.1).

Alice Bell, a researcher in science and technology policy, had made a similar point in *Times Higher Education* in 2012 in which she argued that Open Access may lead to clearer write-up of results if there is the impression that a wider audience may read the article (Bell, 2012). However Allington was not convinced and claimed that "To translate a research article from a technical register into everyday English would ….. make it more ambiguous or more verbose". In either case it would be worse from the perspective of the primary target audience of knowledgeable experts in the field. "Open Access is one thing; expecting researchers to take up the task of public education by radically changing the manner in which they communicate among themselves is quite another". Writing popular science articles is vastly different from reporting on a highly technical research project (see section 5.8.2).

On the central issue of whether expanding the reach of research output was achievable through Open Access, Allington was not convinced. He saw the Green Open Access movement as being a positive contribution to the system as it enables the results of research effort to be shared among other academics. But the real challenge facing the Open Access movement is that a substantial number of academics and knowledge workers cannot be bothered to look for free copies online. Is this a major barrier or one which can be addressed by improved search and delivery systems in future? The openness, transparency, interactivity and cooperation which are features offered by the web and the Internet could provide the mechanisms which will smooth the timely delivery of relevant information to specific target audiences. External change is a powerful force in creating innovative systems to activate latent demand.

Allington was not convinced that social media would provide an adequate surrogate for the journal. Relying on *LinkedIn, Twitter, Facebook* and other social media to provide a secure and reliable platform for scientific communication works against a culture which has a legacy going back centuries.

According to the librarian Rick Anderson "each participant in the system receives distorted and radically incomplete market responses to its inputs" (Anderson R, 2013a). For example there is virtually no competitive pressure on publishers to control journal prices; librarians' collection development decisions are not related to meeting user needs. Allington said that "… the current system is flawed not because journals are over-priced but because….. we do not know what the price ought to be".

Meanwhile the debate rages on what may be considered inconsequential arguments about where the funding flows for supporting scientific publishing should come from – Green, Gold, Grey, Hybrid Open Access , subscriptions, PPV or Big Deals (see 5.2).

4.1.2.6. Peter Murray Rust, Cambridge University

In a blog dated February 2014 Murray Rust, Reader in Chemistry at University of Cambridge, took issue with publishers not being subject to regulatory controls over pricing.

> "Scholarly publishing industry is almost unique in that it provides an essential service on an unregulated monopoly basis. In other words the industry can do what it likes (within the law) and largely get away with it. The "customers" are the University libraries who seem only to care about price and not what the service actually is. As long as they can "buy" journals they largely don't seem to care about the conditions of use (and in particular the right to carry out content mining). In many ways they act as internal delivery agents and first-line policing (on copyright) for the publishers. This means that the readers (both generally and with institutional subscription) have no formal voice.
>
> Because publishers have no regulatory bodies overseeing their operations they operate effective micro-monopolies. Readers have no choice what they read – there is no substitutability. They can either subscribe to read it or they are prevented by the paywalls. If they have access they can either mine it or they are

> subject to legal constraints. Publishers can go a very long way in upsetting its readers without losing market share" (Murray Rust, 2014).

4.1.2.7. Bonnie Swoger, Scientific American

According to Bonnie Swoger, in a blog posted on *Scientific American* (June 18th, 2014), signs are pointing to an academic publishing model based on the article, not the journal. This did not mean that publishers would disappear, but individual journals might not matter much in future. "Even now, articles appear on publisher websites that can make it difficult to tell which journal the article is in". The predominant branding is typically for the publisher, possibly the platform (e.g. ScienceDirect), and the article. Journal branding had arguably become a minor factor (Swoger, 2014).

Fenner has also made a compelling case that the future of scholarly publishing may not lie at the article level, but rather at an even finer grained level where data, analysis, code and other information products have separate (but closely linked) lives (Fenner, 2010). As the call for greater sharing of research data and code grows, researchers are citing data sets more often and scholars are starting to get credit for publishing high quality data.

The business model of for-profit publishers is to favour increasing numbers of journals and seek economies of scale. Creating a new journal is another way to ask for additional subscription fees. But these techniques may not work much longer as open access grows and funders require authors to make publications available. Whilst Ms Swoger does not write an obituary for the scholarly journal, the processes currently in place mean that the journal is not necessary.

4.2. LITERATURE ANALYSIS

4.2.1. Results of Literature Review

The literature review fell into two types of desk research. The formal investigation, using search engines and online bibliographic databses to identify articles relevant to the thesis' topic, and secondly, an assessment of the informal items often in the trade press or social media. As indicated in a Jisc/BL study ('Researchers of Tomorrow') the informal approach should not be neglected within the postgraduate's sources (Jisc and BL, 2012).

Both are a description of a past and present situation rather providing strategic guidelines on how the industry overall copes with change. The online searches described small scale or micro-level studies which gave few insights for developing an overall picture of the current state of the STEM sector, let alone assessing its ability to adapt. The broader search in the informal literature introduced ideas, impressions and opinions which were mainly subjective and anecdotal in their content. Each literature type is valuable, but even together they paint an imprecise picture on how STEM will evolve.

The commentaries which are found in the informal, social media, describe the range of issues facing the STEM publishing industry at present. It gives an impression about pressures building up within the industry. Social media and social networks have become platforms on which fundamental questions about the state of STEM publishing are being openly discussed. They support the key issues in this thesis by questioning whether the traditional STEM publishing system is fit for purpose, whether it is dysfunctional and whether neglect of UKW information needs is one of the casualties.

There is recent evidence, described in Chapter 6.6, of innovative communication services emerging in response to concerns from researchers themselves rather than initiated by publishers and librarians (such as *Mendeley, ResearchGate, Knovel*). This includes new reading patterns being adopted by researchers at the coalface as described by Jeffrey (2012) and Murray Rust (2014). These are more relevant in pursuing the aims and objectives of this thesis than descriptions of small scale user studies contained in published, formal literature.

STEM publishing relies on traditions established in a print-based publishing system. These traditions do not migrate well into the worlds of digital communications and the Internet. Particular problems are exposed in this migration – such as the commercial activities of large commercial publishers; the questionable support for an open access publishing solution; the relative decline in library budgets – which ignore strategic issues of what structural format would best suit a STEM system in the new millennium. Tinkering around the edges is no solution when radical social, technological and economic developments are taking place in the context within which STEM operates (see sections 5.9 and 6.4).

In the many complaints in the informal, social literature about STEM there is one significant omission (though several commentators make passing reference to it). It is the impetus to STEM which would come through opening up access to a wider community of science-aware knowledge workers. These are currently disenfranchised because of the traditional business model of subscription payments inherited from the halcyon days of scientific publishing. UKWs are priced out and locked out from being active participants in STEM.

One recommendation which emerges from the literature review is that more evidence is required on user habits and needs of the unaffiliated knowledge workers so that business models can be constructed as part of strategic initiatives to ensure that STEM develops a healthy approach to information organisation and dissemination over the next decade. That all STEM participants jointly create a vision of an effective research dissemination system in a fully digital environment.

4.2.2. The Information Society

The concept of the 'information society' is fairly recent. In broad terms in the 18^{th}century the UK was largely an agrarian economy, moving on to an industrial economy in the 19^{th} century and the service sector in the early 20^{th} century. It was not until the middle of the twentieth century that the emergence of information and knowledge economies became evident. Only then did the role of knowledge workers become a topic for analysis.

The business consultant Drucker in his book "*The Landmarks of Tomorrow*" (Drucker, 1959) is attributed with coining the term 'knowledge workers'. He was followed by Machlup who provided a systematic analysis of knowledge within the US economy in his book "*The Production and Distribution of Knowledge in the United States*" (Machlup, 1973). Machlup was followed by a similar but more extensive quantitative study by Porat in "*The Information Economy: Definition and Measurement*" (Porat, 1977). Other contributors to the knowledge industry debates included Bell in "*The Coming of Post Industrial Society: A venture in social forecasting*" (Bell D, 1973), and Castells in his "*The rise of the Network Society*" (Castells, 1996). Most recently Webster (Webster, 2014) provided a UK-based assessment of the information economy. His early writings focused on aspects of social change and suggested that information society was more of an extension of earlier trends on corporate capitalism rather than a revolution. He co-wrote a book which critiqued computer and telecommunications technologies, and drew attention to what he felt was the dark side of information developments. This has been added to by Nicholas Carr in his 2015 book "The Glass Cage – Who needs Humans Anyway?" (Carr, 2015) which postulates the growing influence of technology in effecting social decisions in a digital information economy..

4.2.3. The Information Economy

A rigorous treatment of the size of the knowledge worker sector was undertaken by Porat (Porat, 1977). He collected data about information activity in the US economy. Porat proposed a conceptual framework for defining information activities and how to quantify such activity. He was not alone in trying to systematise the information economy. He was preceded by Machlup (1973) and Bell (1973), but Porat's statistical approach and analysis, his input/output analyses, were nevertheless ground breaking.

US society was divided by Porat into six sectors: three information sectors; two non-information sectors, and a household sector. Three information sectors produce and distribute all the information goods and services in support of the economy. The two non-information sectors supply the physical or material goods and services whose value or use do not primarily involve information, but nevertheless have relevance. The household sector supplied labour services and consumed final goods.

Porat identified 26 information industries that constitute the primary information sector. He also made reference to the contribution from secondary information sectors which accounted for 82 non-information industries.

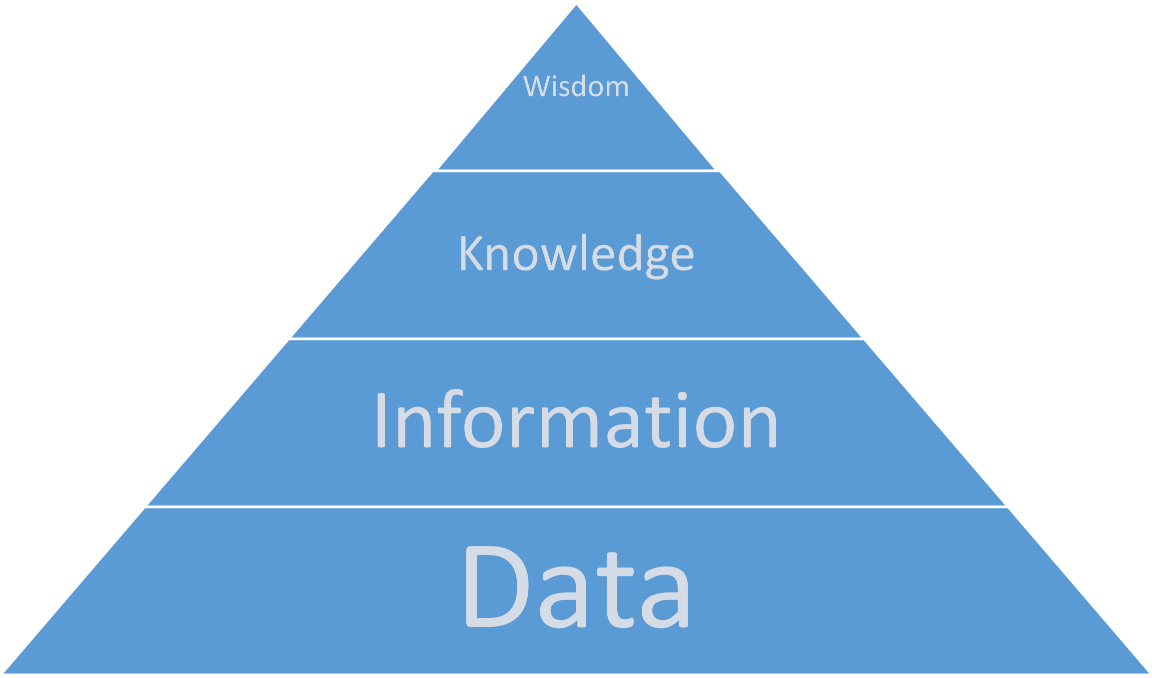
Porat concluded that 25.1% of the USA Gross National Product in 1967 was bound up with the primary information economy which is where information is exchanged as a commodity. The secondary information economy includes information activities produced for internal consumption by government and other organisations, where it is embedded in some other good or service and is not explicitly exchanged; this amounted to an additional 21% of the US economy. According to Porat nearly half the labour force held an information-related job. By 1967 the information sector became dominant rising from a low of 15% of the workforce in 1910 to over 53% of all labour income in 1967.

Conceptually, he claimed that 'information' cannot be condensed into one sector – such as mining – but rather the production, processing and distribution of information goods and services should be seen as an 'activity' or utility operating across all industries. There are other unique aspects applied to information which have become folklore. Information has become a utility which does not depreciate over time; in fact, its value is enhanced with age and usage. Information also has a non-rival aspect in that it does not preclude others from making use of the same information without anyone incurring a loss. Furthermore, in theory it is non-exclusive in that anyone could make use of information. However, in practice STEM has surrounded the research article with constraints such as copyright and intellectual rights protection which affects its open availability. Furthermore, information is cumulative, 'building of the shoulders of giants' as new research results build upon past endeavours. Finally, information is now digitisable which creates new opportunities for its dissemination through digital networks using different business paradigms. These factors taken together emphasise STEM-related information is unique.

Machlup produced a similar treatment to Porat of the US information economy (Machlup, 1973).   Machlup's accounting scheme began with five major classes of knowledge production, processing, and distribution, and 30 industries that were classified into (i) education, (ii) research and development, (iii) media or communication, (iv) information machines and (v) information services. Machlup's estimate of total knowledge production of $133,211 billion (1958) compares with Porat's $71,855 billion for the same year. The difference is accounted for in the latter's exclusion of secondary information services.

Another approach to understanding the information economy has been put forward by Ackoff who promoted the idea of there being an information pyramid (Ackoff, 1989).

Graph 4.1. Ackoff's Information Pyramid



Legend: *Information* is data that is processed to be useful; provides answers to "who", "what", "where" and "when" questions. *Knowledge:* application of data and information; answers "how" questions. Understanding is an appreciation of "why". *Wisdom*: evaluation based on knowledge and understanding.

At the base of the pyramid are vast data resources. Data by itself has limited value. Above this is information, which in itself has become a problem as 'information overload' has entered the vocabulary (one of the first mentions being by Toffler in his 1970 book 'Future Shock' see Toffler, 1970).

By the mid 1990's the concept of knowledge and understanding had been built on top of the information stratum. Whilst information has become 'structured data', knowledge has become ‘actionable information’. Knowledge is about the filters in place, reducing the ‘fire hose’ of what is available to what we need to know. Filtering and linkages are a key phenomenon of the digital age, as they were in the printed era. At the top of the pyramid is wisdom. Wisdom requires broad connectivity whereby associations and decisions are drawn from an ever wider range of experiences that enable the assignment of more generalised values (Greenfield, 2015 p98).

Relevant to the STEM information sector, there is the quaternary sector which covers everything from universities and higher education to the pharmaceutical industry, computer software, technology start-ups - sectors that involve the use of knowledge to create something new of value. It does not cover financial services, banks and medicine as they are part of the service economy, or tertiary sector.

Such analytical studies of the information economy shed light on how significant an asset information has become in a modern economy. Good information oils the machinery of the economy and fuels its expansion. It therefore behoves society to ensure that barriers and obstacles which are in place in any part of its operations, affecting its dissemination and use, should be understood and where required, dismantled.

4.2.4. Global Information trends

In 2015, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development. “For the first time at this level, the role of science, technology and innovation has been explicitly recognised as a vital driver of sustainability. Sustainability depends on the capacity of states to put science at the heart of their national strategies for development, strengthening their capacities and investment to tackle challenges, some of which are still unknown” (Unesco, 2015). Given that STEM oils the research and innovation processes, this highlights the significance of the issues being addressed in this thesis.

The world devoted 1.7% of its gross domestic product (GDP) to R&D in 2007, a share that has remained stable since 2001. In monetary terms this translated into US$ 1,146 billions in 2007, an increase of 45% over 2001. This is slightly higher than the rise in global GDP over the same period (43%). Despite global economic problems, countries still spend on R&D as a way of stimulating new economic growth and buying themselves out of austerity (Unesco, 2010).

Science has been growing at a steady rate during the past few decades though there is controversy over how much actual growth has occurred. The difficulty is applying a realistic measurement system for science. One possible measure is to relate growth of science to growth in output of scientific publications. Though Mabe and Amin (2001; 2003) authored articles in the early 2000's to show that science publishing and science grew at a steady 3% to 3.5% per annum, this has been challenged by some authorities, and figures in excess of 4% have been suggested (+4.7% per annum by Thomson Reuters, a leading organisation providing data on scientific publishing – see Adams et al, 2009).

The problem is comparing like with like. Whether just the core natural science journal outputs have been looked at (which show a slower growth rate than some of the newer sci/tech disciplines); whether conference proceedings are included (with conference proceedings more important in scientific fields with high growth rates); whether other social media are included; whether institutional repository holdings are included; these all have implications on the overall growth estimates for science and STEM publishing.

There are also regional differences in R&D. BRIC countries (Brazil, Russia, India and China) and VISTA (Vietnam, Indonesia, South Africa, Turkey and Argentina) have until recently been expanding their research commitments at a faster rate albeit from a low base. The developed world is maintaining a steady annual increase in its support for R&D, though China and India have become powerhouses in global R&D activity. The needs of developing countries for research information mirror the needs of unaffiliated knowledge workers within the UK. Both suffer exclusion from the fulcrum of research activity – both stand at the periphery looking in at the western academic-based research effort but being unable to interact or communicate with its research on a level playing field. Both the developing nations and UKWs in developed countries face the challenge of breaking down the barriers to scientific information access and interaction.

Therefore the question which underpins this thesis is how equitable and evenly spread commoditised information is, particularly among academically trained users of research information. And if, as is the starting hypothesis for this research, there are barriers in place preventing interested parties from gaining equal and ease-of-access to required information sources, how can this situation be remedied?

4.2.5. Environmental Developments

The consensus among observers of the STEM scene is that the industry is at the cusp of major operational changes. There is need for all stakeholders in STEM, notably publishers and librarians, to adapt to the changes which are taking place as the industry migrates from a print-based format of research dissemination to the current hybrid approach, and in future to a fully digital information environment.

The conditions creating this new environment are outside the control of existing players in the STEM business. The environmental conditions are part of an ever-increasing sophistication within society driven by improvements in technology and changes in business practices. STEM publishers have remained immune from such developments, adopting a position which has strong roots in a legacy system of print-based publishing and a reward system which is conservative in structure. Publishers face having to make a major change in their strategic policies (see valley of death, section 5.14.4.4) or succumb to being by-passed.

There are some powerful agents for change which will have an impact on this cautious, traditional business sector.

4.2.5.1. A 'Perfect Storm'

A perfect storm is when a number of unrelated factors come together to create dramatic consequences. In this instance the factors are sociological, technical, political/administrative, economic/commercial, openness and trends in the research process itself. The consequence is that STEM communication will witness a change in its size, nature and shape and over which it will have little control. The factors which lead to this changed environment are partly general trends and partly significant individual drivers. These are described in detail in chapter 5 (for trends and drivers relevant to UKWs) and chapter 6 (for trends relevant to the structure of the STEM publishing industry).

The combination of these trends addresses 'latent demand'. They relate to occasions in which researchers outside academia would benefit from access to STEM research output - but to obtain this today in the traditional form is forbidden, confusing and costly. The perfect storm forces may enable latency to be activated and brought within the emerging research domain.

4.2.5.2. Emerging Trends and Procedures

This thesis categorises those changes which are impacting on STEM and UKWs in future according to the following main groups.

For UKW issues:

- Neurological issues ('rewiring the brain)' – see section 5.9.2.1
- Demographic trends (increasing graduates and general 'science-awareness') – see section 5.10
- Adoption of Social Media and social networking – see 5.12
- Research procedures (sharing and collaborations) – see 5.9.2 and 5.9.3
- Technology adoptions – see 5.9.4

For STEM industry

- Financial/Commercial (business models, including open access) – see section 6.2.5.1
- Publishing digitisation particularly in the STEM area – see 6.4.2
- Developments in the science research process – see 6.4.3
- Science policy issues – see 6.4.4

These concepts – brought together in this way – constitute a novel contribution which this thesis offers in advancing knowledge and understanding of the STEM communication industry and where UKWs can fit in. There are external-generated social and cultural trends which are generally overlooked by STEM observers. Yet these socio/cultural trends will have an influence on usage patterns within the research community. One area of significant change could be in the way a more democratic distribution of the results of public-funded research could be undertaken. This is where the latent demand for science information among the unaffiliated knowledge worker community becomes an important information policy issue.

The key challenge will be for the STEM industry to come to terms with future challenges. The changes outlined above will lead to pain and suffering as well as opportunities and benefits for STEM in the emerging digital environment.

5. RESULTS 1: UNAFFILIATED KNOWLEDGE WORKERS

This thesis' primary focus is to investigate those who are referred to as unaffiliated knowledge workers (UKWs). They are a sector of society which has been excluded from the nation's formal scientific activity because of constraints inherited from a traditional print publishing system. Examples of UKWs are described in this chapter.

Methodology

Methodological techniques employed in this chapter involved desk research and analysis of both text-based publications and datasets. It also included interviews and results from two online questionnaires. Social media and grey literature sources were also drawn upon. In particular, the opinions of eminent authorities in the STEM area were sought and analysed. The aim was to effect a 'mash-up' of these different sources and thereby develop concepts which can help define the transformation processes STEM will go through in its migration into the digital age. In so doing the implications this has on UKWs has been analysed.

Lack of research relating to the information behaviour of UKWs is particularly poignant as it is through meeting defined needs of this community that a new and modern direction to STEM communications could be initiated. Several studies have been made of researcher behaviour but only within the higher education sector. These studies gave a picture of the current scene, a snapshot in time and of small samples of the overall universe of over 7 million researchers worldwide. The problem with relying on these reports is that they describe events during which, at worst, the print paradigm prevailed - at best they described a hybrid world of researchers coping with a mix of print and digital. There are few studies dedicated to studying total immersion by researchers in a digital world which includes social media, datasets, artificial intelligence and cognitive computing services.

Attempts made by this author to identify user behaviour are included as case studies in the appendices 3.1 and 3.2, and also in the notes of meetings with active researchers, but the numbers involved are small (up to 50 interviews held overall). They explored attitudes towards new technology in STEM based on opinion and not evidence. Nevertheless, the approach here was investigatory/original research to complement the desk research.

This is not a static situation and longitudinal user studies are required on how research behaviour changes over time. Designing new information services to cope with change is difficult and highly subjective. There are some notable examples of disruptive technologies transforming information society which have occurred during the past two decades which could not have been foreseen at the time - the proliferation of PC's, the adoption of Google, Facebook, and the reliance on smartphones, etc. To factor such disruptive events into a strategic STEM assessment, or on UKW user needs, requires a leap of faith. Nevertheless having alternative visions of the future is an improvement over no vision at all.

This has meant that a large part of the methodological approach has been to analyse the opinions, views and thought-provoking commentaries of experts. These experts, mavens or gatekeepers were selected on the basis that they are referred to in the media and seen as making significant contributions to strategic analyses in the information industry. Their views on industry trends were elicited through desk research in both formal and informal literature, and were subsequently scrutinised and subjected to critical analysis. This MPhil project is a strategic assessment rather than operational, and as such depends for its success on the quality and provenance of the opinions identified. Though not following the strict procedures of a Delphic study (Pickard, 2013), it was felt that bringing the written thoughts of these experts into a structured assessment, that this approach was as close to Delphic as was possible.

To complement the written views of experts, face-to-face discussions were held with over twenty representatives from the STEM industry to assess the validity of the findings from desk research. This included meetings held with representatives from UKW sectors, notably learned societies such as the Institute of Mechanical Engineering, Institute of Chemical Engineers, Institute of Directors, Institute of Technology and Engineering as well as the current ceo of the Association of Learned and Society Publishers. These meetings involved a semi-structured questionnaire being used, giving overall guidelines which were followed during the discussions, but also allowing each contact to input relevant issues of particular interest or concern to them. The results of the meetings were assessed through discourse analysis. This gave latitude to the author of this thesis to consider how the issues raised related to points made by earlier contacts as well as putting information culled from the literature analysis into context. The process has been iterative over the seven years of this project's evolution.

Collection of source material also included desk research among grey literature sources. Commentaries in newspapers, magazines, newsletters and blogs were identified and evaluated. These were mainly used to check claims made about the benefits or problems in the adoption of social media by the wider net generation community. The approach here involved critical analysis.

Sources for statistical data have been the Office of National Statistics, UK Higher Education Funding Agency, and the UK Department for Business, Innovation and Skills. Their outputs gave scale to the issues facing unaffiliated knowledge workers. Assessments of the data have been made to reconcile differences in data collection approaches by the different agencies, and the lack of data transparency and comparability is highlighted.

There are other research methods which could have been employed – research surveys or action research for example. In addition, other ways of identifying key tipping point factors in the transformation of STM could have included small and therefore possibly unrepresentative sampling methods being used to collect ideas and evidence. Although this has the potential to generate much noise and partial judgments, which could have clouded key issues, two online questionnaire studies among researchers were in fact undertaken. These were more to set the scene, at an early stage in this project, rather than to be used as a substantive source for measuring overall industry opinion.

More factual evidence on researchers' needs and habits in accessing STEM material is required. This would provide a foundation for formulating effective strategic visions among STEM, knowledge workers and UKWs in the future. In designing such future research projects it would be important to extend the scope of the study beyond the traditional areas of academia and corporate R&D to include knowledge workers in general and UKWs specifically.

5.1. OVERVIEW OF UKWS

The following social groups are identified as unaffiliated knowledge workers:

- Many *professionals*, outside academia, rely on high level research results to sustain professional standards. Their aim is to improve professional practice by adopting latest developments affecting the profession. These can be reported in specialised research journals and other research outputs. Such journals are not readily accessible to individual professionals.

- There is emphasis - in a society striving to achieve improved lifestyles, economic growth and to overcome financial austerity - on supporting researchers within *small and medium enterprises* (SMEs). They are at the forefront in developing innovative products and services. SMEs need regular access to information arising from relevant STEM developments. Several SMEs are spawned within university laboratories and subsequently floated off in industry, either in partnership with the university or as private ventures. (The author has first-hand experience of one such flotation in BIDS' transfer from academia to the private funded Ingenta in 1998). However, once the umbilical cord with academia has been cut, easy access to STEM is curtailed. Currently, the publishers' main audience is the larger, wealthier research institutions and corporations. These latter, large corporations, may have information and documentation centres. They or more likely to have sufficient funds to buy subscriptions to STEM journals. SMEs are not so fortunate and need to find other ways to remain informed.

- There are many '*citizen scientists'* or 'amateur scientists' who have chosen to pursue careers outside academia and corporate R&D but who retain an interest in the subject of their early academic training, or they have recently developed new scientific interests. They have also taken the resources available on the web and Internet on board. Mass-collaboration by this group can be seen in global scientific projects such as the Sloan Digital Sky Survey (SDSS) in astronomy (see section 5.6). These lead to large data webs being created which involves participation from thousands of amateur scientists.

- Another professional area is in the *agrarian, horticultural* and related *land management* industries. They are reliant on science and technology to generate greater efficiency and higher crop yields. Easy access to high level research results in genetic engineering, veterinary, environmental data and biological research results amongst others are beneficial to agronomists. Again, these communities have barriers to overcome in gaining access to required scientific updates.

- There are *lobbyists* and *charities* in the private sector which bolster their missions with hard evidence drawn from scientific output, and are pushing for change to limit the onset of global climate change, to eradicate pollution, to improve social conditions, to save on energy, etc. In addition, *science writers* and *journalists* also feed on accessible scientific literature which may or may not be easily available to them.

- *Consultants* who have clients in science-related industries are also interested in STEM material. The current business model would not be a strong deterrent to buying required material, whereas search and finding material in the dark areas of the Internet and social media might. Consultancies can be found both in public and private sectors (see section 5.5.4).

- There are *administrators* and advisers, who though at the fringes of the academic publishing system, influence directions which the research sector takes. There are also policy makers in government and among funding centres involved with implementing research programmes. Voluntary associations and charities are also included in having an unfulfilled need for ease of access to relevant STEM material.

- Even for those operating within the *UK higher education* system, in universities and research institutes, access to scientific information is not always easy because of the barriers which operate within academia. This group would also include *alumni* and friends of the university. It also includes impatient academics unwilling to wait for required texts to be supplied through traditional document supply channels (see section 6.3 on Dysfunctionality of STEM).

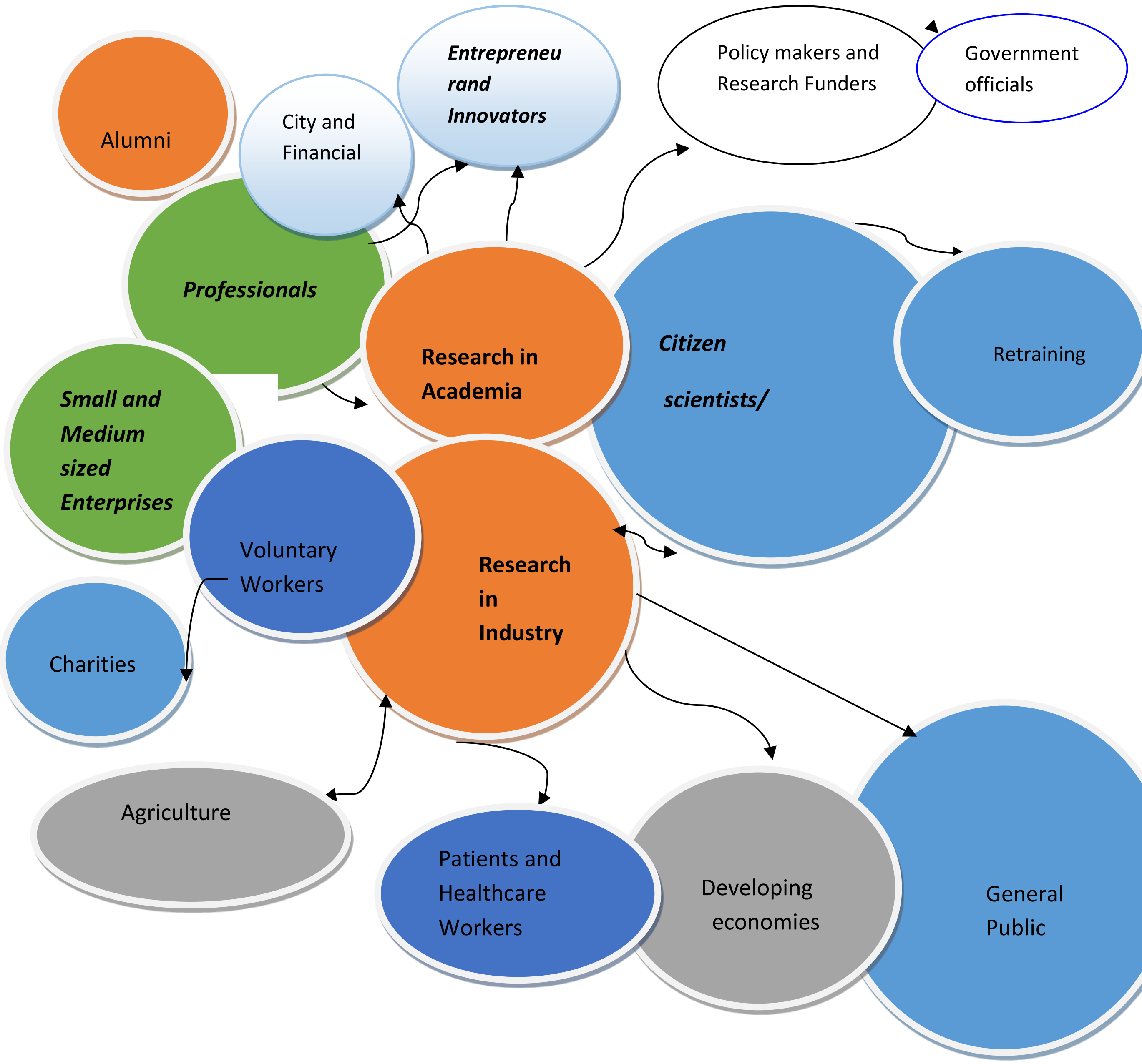
- Other knowledge workers operate within public libraries, trades unions, Chambers of Commerce and the Confederation of British Industries (CBI).

- There are other disenfranchised communities and knowledge workers operating in *developing countries*. Their approach of leapfrogging into the STEM information systems could affect the global future publishing paradigm.

- There are also many *others.* A requirement for access to research information can be found in areas such as engineers working in remote offshore installations where no library facilities exist; individuals working in financial institutions which are prepared to invest in new scientific-based businesses and have occasional need to find more about projects. Also included are people retraining or developing new skill sets; distance learners and those facing geographical challenges in accessing research libraries; patients who are seeking everything there is to know about the illness from which they or their relatives are suffering - to know as much if not more than their over-stretched general practitioner.

The following diagram gives an indication of some of the areas which may include unaffiliated knowledge workers in the UK.

Model 5.1. Overview of main areas of knowledge workers



Although the Unaffiliated Knowledge Worker sector included in the above graph and description is large and diffuse, there are three main target groups which are the focus of this thesis.

- The Professions
- Small and Medium Enterprises (SMEs)
- Citizen Scientists or armchair scientists

In addition, the above three are sandwiched between two other groups which have influence over the direction which communication within the STEM research sector will take. These include:

- Academics in academia who also face access barriers
- The General Public, those without advanced level academic qualifications or professional experience in the sciences

These will also be addressed in this chapter as being knowledge workers having unmet STEM information needs.

5.2. KNOWLEDGE WORKERS

It has been estimated that there are about 500 million knowledge workers globally (Microsoft, 2010), only 30 million of which are in academia/corporate research areas. A recent and more reliable estimate gives 50 million knowledge workers in the US alone (only 8 million of which are in academia, the rest in the private sector – see NSF, 2010a and 2010b; Padley, 2014). Mabe (CEO of International STM Association) suggested that there were some 35-40 million who were non-institutional knowledge workers (Mabe, 2009). This suggests that there could be between 200 million and 500 million knowledge workers worldwide.

This is a large latent market for scientific material, and compares with the 7 over million actual researchers worldwide identified by Uneso (Unesco, 2015).

"Virtually nonexistent only 100 years ago, knowledge workers now make up the largest slice, 40%, of the American workforce" claimed business management guru Drucker over fifty years ago. He further suggested that "Knowledge worker productivity is the biggest of the 21st century management challenges....(it is the) only real competitive advantage in a global economy" (Drucker, 1959).

The knowledge worker sector continues to grow. According to Morgan Stanley's economist Roach "This is, by far, the most rapidly growing segment of white collar employment. Over the past seven years .... knowledge worker employment growth has averaged 3.5% per annum, sufficient to have accounted for fully 73% of total white collar employment growth over this period" (Roach, 2007).

Forrester Research claims that American workers spent $404 billion annually, or 11% of all wages, looking for information to do their jobs. Giving employees the right tools in a data- and knowledge-driven workplace is imperative (Forrester, 2001).

5.3. KNOWLEDGE WORKERS IN UK

There are an estimated 11.1 million knowledge workers in the UK (see: Office of National Statistics, 2011) which contrasts with the numbers in UK academia of 2.5 million (HESA, 2010).

In a 2009 report to the British Government ("*The Panel on Fair Access to the Professions*", 2009) it was estimated that almost half the UK working population was in 'the professions'. As this included creative arts and public sector workers, the actual numbers in the core professions was about half that number or 5.5 million. These estimates are different from the data which was made available by the Department of Business, Innovation and Skills (UKDBIS, 2011) which focuses on core R&D activity. UKDBIS concluded that there were 1.8 million R&D workers in the UK in 2009 (see below). "Of these a considerable but uncertain proportion are unaffiliated, without corporate library or information centre support" (Rowlands and Nicholas, 2011). This indicates that the awareness of the demographics of knowledge workers and UKWs is statistically weak.

The following table looks at the breakdown of the 'official' knowledge workers in the UK as derived from the Office of National Statistics (ONS, 2011).

Table 5.1. Broad sector knowledge workers (1-digit SOC code)

		UK Knowledge workers			
SIC (2003)	**All workers in sector**	**Manager s and senior**	**Professio nal Occupatio**	**Total**	**% KW**
Mining	75,486	11,519	21,827	41,046	54%
Manufacturing	2,391,224	475,352	212,078	902,534	38%
Electricity, gas	2,638,066	380,940	163,073	660,992	25%
Construction	272,420	37,716	3,162	45,981	17%
Wholesale/retail	3,868,434	802,137	76,278	1,106,048	29%
Hotels/restauran ts	1,161,424	209,070	5,992	245,126	21%
Transport, storage	2,054,377	392,405	98,724	663,694	32%
Financial	848,105	221,838	68,400	536,059	63%
Real estate, renting	4,075,175	784,832	918,725	2,515,893	62%
Public & defence	1,891,049	115,029	486,412	1,030,877	55%
Education	3,219,338	166,183	1,117,363	2,044,167	64%
Health/social work	1,983,382	216,858	165,874	752,120	38%
Other community, social and personal	1,386,065	157,395	103,828	589,154	43%
Total	26,142,446	3,998,338	3,443,716	11,163,56	43%

Source: Reworking of Office of National Statistics (Labour Force Survey) data, 2011
Total knowledge worker column includes figures for 'Associate professional and technical workers'.

Not all the above knowledge workers are at the coalface of research, nor require access to the latest STEM developments. But some are – and their performance could be enhanced if they were able to gain the same level of access to relevant items of research literature as their colleagues still working in academia.

The breakdown of the numbers of Research and Development professionals by category in the UK can also be seen in data presented by the Department Business, Innovation and Skills (UKDBIS, 2011).

Table 5.2. Numbers of R&D professionals in UK business sectors

Professional Sector	Numbers employed (BIS)	Percentage of total professions
Industrial & Engineering professions		
IT strategy & planning	129,074	7.3%
Civil engineers	78,669	4.4%
Mechanical engineers	67,914	3.8%
Chemical engineers	4,294	0.2%
Design & development	46,899	2.6%
Electronics engineers	22,992	1.3%
Production & process	19,823	1.1%
Planning & quality eng	18,465	1.0%
Quantity surveyors	41,236	2.3%
Bioscientist Biochem	42,074	2.4%
Pharmaceutical	37,670	2.1%
Physicists, geologists	8,435	0.8%
Subtotal	517,545	29.1%
Service sector		
Medical profession	204,350	11.5%
Dentists	33,098	1.9%
Opticians	13,833	0.7%
Software professionals	277,408	5.6%
Solicitors, lawyers	150,043	8.4%
Legal profession nec	17,164	0.9%
Managemt, business	136,615	7.7%
Accountants	128,402	7.2%
Management account	54,158	3.1%
Psychologists	22,015	1.2%
Social science res	8,944	0.5%
Social workers	99,979	5.6%
Probation officers	12,007	0.6%
Public service	24,993	1.4%
Architects	45,933	2.6%
Town planners	21,187	1.2%
Veterinarians	12,282	0.6%
SubTotal	1,262,411	70.9%
TOTAL	1,779,956	100.0%

Sources: “The sectoral distribution of R&D”, 2009 R&D Scoreboard. U.K. Department for Business, Innovation and Skills”

The above table shows the extent of the UK’s service economy - over 70% of R&D professionals are in the service sector with software and medicine responsible for a quarter of all such professionals. Engineers amount to 14%. There is a large distribution of professionals in other areas – some 30 identified above, and this is not exhaustive.

Despite the differences in scale between UK knowledge workers overall and those who are classified as being research-based professionals, it is clear that there are individuals in the private sector whose performance could be improved if they were given ease-of-access to the world's research outputs. Few may be interested in the hard core of STEM material (in nuclear physics or bioinformatics, for example) but many could have interest in the output from less specialised and esoteric subjects. As observed by Brienza "the number of people who might learn from research results is always going to be greater than the number likely to actually seek out what has been written up" (Brienza, 2011, p 168).

There is no means of establishing what proportion of knowledge workers are 'affiliated' to a central purchasing scheme for published scientific content. This area requires additional study through targeted in depth 'niche' sector analyses.

In addition, this is only a small part of the total potential market size. It excludes a vast audience of 'citizen scientists', those who have a general interest rather than a career requirement in following scientific developments. They are excluded from ONS's 11.1 million UK knowledge workers, and also not included in UKDBIS's 1.8 million R&D professional numbers, nor the 2.5 million in academia (HESA, 2014).

The following more detailed analysis of individual UKW areas highlights their variety and scope.

5.4. THE PROFESSIONALS

Methodology

Though statistics figured prominently in assessing the scale of UKWs, several meetings were also held with representatives from learned societies. These meetings involved a semi-structured questionnaire being used to collect original research data for this project.

The results of the meetings were assessed using discourse analysis. This allowed the author of this thesis to consider how the issues raised related to points made in the informal literature.

Additional material came from publications in formal literature. In particular a major study of UK professions (Susskind, 2015) was included in the assessment as it gave an independent assessment of the future for the professions overall, one which coincides in many respects with the adverse assessments given for STEM in this thesis.

5.4.1. What is a Profession?

There is no clear definition of a 'profession'. Several groups stand out as obvious professionals - lawyers, doctors, accountants, librarians, for example. But there are many which are less obvious - management consultants, local authority workers, journalists. In 2009 a report for the UK Government identified 130 different professional sectors ("*Panel on Fair Access to the Professions*, *Unleashing Aspirations"* (2009)).

Professions can be defined as a collection of individuals who have a 'formal education' requirement (Wilson, 1989). However, to distinguish professionals from academics, it is often claimed that the former have a practical knowledge base as well as a theoretical one. Also, a professional is someone who receives important occupational rewards from a reference group whose membership has undergone similar specialised formal education/training, and accept a group-defined code of conduct and practice. The main features of a profession are:

- There are conditions of entry
- It has rigorous standards
- There are specific and unique rules of conduct
- It is either self- or statutory-regulated
- The profession has accountability
- The profession offers training and support
- There is a knowledge base (which often has roots in formal higher education/research)
- It has a distinctive and identifiable social mission

(Source: Wilson, 1989)

Professionals perform specialised, unique and scarce services - services which differentiates them from the general public. Secondly, they pay as much if not more attention to the judgement of their peers (other similar professionals) as to the judgement of their customers when deciding how to perform their tasks (Shirky, 2008). There is abeyance by a professional to a set of standards, procedures and approach to ensure that professional status is not compromised. Furthermore, those professions having technical roots in advanced science subjects and higher education are comparable with academic researchers in understanding scientific concepts, and as such have the need for comparable ease of access to relevant research outputs.

Professionals differentiate from academics in the following:

* They differ in their response to peer pressure
* They have different funding drivers
* They rely on precedent created by practical experience
* They differ in their success criteria
* They do not seek global recognition to the same extent
* Their main allegiance is to their professional association
* They operate outside the closed (elitist) system of scientific research

In essence, a profession exists to solve a problem, one that requires scarce or unique expertise/experience to reach a solution. However, in trading on such scarcity they have been criticised by some sociologists for not so much acting as benevolent custodians of their knowledge/expertise as being jealous guardians of the knowledge base to the detriment of society (see below in 5.4.3 and in chapter

7 on Learned Societies).

5.4.2. Indicative list of current professions

The following is an indicative list of professions which operate in the U.K.

Table 5.4. Partial List of professions

Accountants	Actuaries	Advocates	Architects
Archivists	Audiologists	Dentists	Diplomats
Medical Doctors	Economists	Engineers	Financial analysts
ICT	Veterinarians	Journalists	Lawyers
Military Officers	Neuroscientists	Occupational therapists	Optometrists
Nurses	Pharmacists	Philosophers	Physicians
Pilots (airline)	Professors	Psychologists	Scientists
Social workers	Software engineers	Speech Language	Pathologists
Statisticians	Surgeons	Teachers	Translators/interpreters

The above list is not complete – there are more professions and sub-professions, and many more emerging as digital society advances and creates new services. This is particularly noticeable in the ICT, financial services and business sectors.

5.4.3. Challenges facing the professions

What is unclear is whether a professional - within the current period of digital migration - is one who puts service to society above riches and profits. There is a suggestion that the ‘grand bargain’ between society and the traditional professions, in which society grants professions control over their affairs, is breaking down, and profits are increasingly trumping client focus or interests (Susskind, 2015). This means that the highly structured and inflexible professions as we know them - lawyers, medical doctors, accountants - will be supplemented with a new set of proxy-professions in future. These will rely on different skills sets, involving both automation and innovation to take over the profession’s mundane and repetitive tasks, to effect by-pass strategies over parts of the professional establishment. More IT literate sub-professions will emerge with differing, less elitist and less exclusive approaches to meeting career goals. The core of professional skills will still remain but many aspects of the current functions will be devolved to others, including to online support services. However, they as well as their predecessors, will have a need for ease of access to research output.

The problem facing professions is that they seek to protect themselves by focusing on their skill set without taking into account new ways of doing similar work arising from IT and Internet developments. An analysis which explores potential redundancy of some professionals was contained in the book "The Future of the Professions: How Technology Will Transform the Work of Human Experts" (Susskind, 2015), The authors describe how 'increasingly capable systems' - from tele-presence to artificial intelligence - will bring fundamental change to the way that the 'practical expertise' of specialists will be made available in society. The book predicts the decline of the protected infrastructure surrounding today's professions and describes the people and systems that will replace them. In an Internet society, according to Richard Susskind and Daniel Susskind, we will neither need nor want doctors, teachers, accountants, architects, the clergy, consultants, lawyers, and many others, to work as we knew in the 20th century.

Three reasons are given for an assumed reduction in employment within the professions (and the rise of para-professions). The first is that computers will continue eroding the advantage people currently have in performing certain tasks. Secondly, new latent demand will be accommodated within the capabilities of machines, and thirdly, whilst the machines cannot yet make moral deliberations or take moral responsibilities, the volume of these will be insufficient to keep professional employment on today's scale (Susskind, 2015, p 291/2).

The authors therefore claim that current professions are antiquated, opaque and no longer affordable, and that the expertise of the best benefits only a few. The book raises important practical issues. In an era when machines can out-perform human beings at most tasks, new occupations will arise. In education, the 'sage on the stage' method of teaching is being complemented, or replaced, by companies providing 'adaptive' or 'personalised learning' which use computers to assess specific needs of the individual student, and 'intelligent learning systems'. A tailored approach to instruction is offered, as opposed to reliance on the traditional teacher/student interaction which is more general and systemic. MOOCs (Massive Open Online Courses) have opened up a new approach for education from centres such as MIT, Harvard and Stanford.

In health care, the provision of personal health records from cradle to grave, matched against indicators of potential illnesses, could provide a more personal service than the delayed advice and consultancy services currently available from the GP. However, many doctors may soon find themselves taking on the role of human sensors who collect information for a decision-making computer. The legal profession, for long the archetype of a protective profession, has become more 'open' in the UK in recent years as the monopoly over offering law services has become liberalised which has benefited non-legal agencies. Journalists have seen the arrival of online newspapers, sourced in part by individuals on site of a newsworthy event rather than professional journalists. Printed daily newspapers have been in decline, and usage of online news access in the UK has risen from 20% to 55% in seven years (Susskind, 2015).

Methods for charging services which are provided - the business model - is undergoing change. Many professions are moving away from an hourly charging rate to fixed fees for outputs. This in response to criticisms over high costs for traditional professional services. The conclusions - that the established professions will be disrupted - are based on in-depth research by Susskind in more than ten professions. (See chapter 7 on UK Learned Societies).

Professions as they currently exist may be subject to change - nevertheless the main functions they perform will in most cases continue, albeit in different guises. Though professional regimes may change, Susskind believes future roles will include:

Craftspeople	Assistants	Para-professionals	Empathisers
R&D workers	Knowledge engineers	Process analysts	Moderators
Designers	Systems providers	Data scientists	Systems engineers

The above list of emerging professional support groups is again not comprehensive. "Even highly trained analysts and other so-called knowledge workers are seeing their work circumscribed by decision support systems that turn the making of judgements into a data-processing routine" (Carr, 2016 p17). There are indications within some established professions that change in the way they control, collect and assimilate STEM information is occurring. Whilst this suggests growing liberalisation for professions - a reduction in the control which the profession exerts over the services they provide - such splintering of the professional service package still needs control procedures to be built into the operations of these new para-professional groups.

Professional organisations are going through the same painful adjustment to the digital world that the STEM publishing industry is going through. The following section describes how several established professions have so far coped with access to online information.

5.4.4. User Behaviour

5.4.4.1. User Behaviour of Business researchers

Users of business information differ from other professionals and also from academics. There is an emphasis on immediacy and topicality. Digital and online are preferred delivery options for information. Timeliness can be translated into money and profits. In order to meet business information needs an understanding is required of the purposes for which information is needed, the environment within which the user operates, the skills required for identifying the needed information, the speed with which information should be delivered, and preferred channels to be used.

As Kanter (Kanter, 2003) highlighted, information has become a critical asset for companies. Good and reliable sources are required. However, only one quarter of business professional respondents to his study physically visited a library at least 2-4 times per week. This increased by a further 17% when monthly visits were considered, and by 44% for a semester. Therefore, though heavy use is made of electronic information, access to a library with its physical store of print and electronic material is still only an occasional event among business practitioners (Kanter, 2003).

In March 2008, the consultancy group Capgemini UK published a report entitled “The Information Opportunity” (Capgemini, 2008) which suggested the estimated annual costs associated with bad decision making being made across UK businesses and the public sector as a result of poor or inferior information access was £67 billion. The report, based on in-depth interviews with senior leaders from FTSE 350 and UK public sector organisations, found that there was ‘a broken information culture’. The values and behaviours associated with how they collect, use, manage and share information was not working efficiently.

It would be misleading to claim that STEM information is at the forefront of the information challenge facing business professionals, but it could be part of the challenge. Management of critical information for business decision-making is a concern affecting the entire private sector – from SMEs to large multinationals. With over three million entrepreneurs and two million managers in the UK the numbers are a sufficient inducement for developing a range of STEM support services which meet their particular needs.

5.4.4.2. User Behaviour of Economists

Learned journals for economists ceased being a primary way to disseminate information some 25 years ago, replaced instead by working papers (grey literature). This switch away from journals was partly because of the long publication time lags - as one commentator claimed, by the time his most successful academic paper was published (in 1991) there were around 150 derivative papers in circulation (Krugman, 2013). In other instances, rigid ideologies blocked new ideas. Rogoff wrote about the impossibility of publishing macro data in the face of this “new neoclassical repression”.

Key discussions in macroeconomics, and to a lesser extent in other related economics fields, is taking place in the econoblogosphere. This is true even for research done at institutions such as the International Monetary Fund and the US Federal Reserve. Researchers read working papers online, and that is how their work gets incorporated into the community’s discourse.

5.4.4.3. User behaviour of Engineers

In a survey of 200 engineers undertaken by the New York-based entrepreneurial Knovel information service in 2013, among mechanical engineers from companies with more than 1,000 employees, global search engines surpassed printed material (including books and manuals) as the first place engineers go to find equations. 92% of engineers searching online rely on public search engines (such as Google), up from 41% in 2010.

Although Google is the first place engineers turn to, it is the least satisfying for results. Items are now easier to find online, but specific equations on Google are not among them. Engineers conduct more searches for equations online, but they are dissatisfied with the results (Knovel, 2013). Opportunities exist to provide refined STEM services among engineers as new technology is introduced.

5.4.4.4. User Behaviour of Life Scientists

Researchers at The University of Edinburgh undertook a study for RIN and the British Library into how information is used across the life sciences (Univ of Edinburgh, 2009). They found that there were strong variations in user behaviour between the seven life science research teams analysed. The research topics varied from botany to clinical science, and were investigated using in-depth daily research probes or lab books from 56 participants over nearly a year. Some of the specific findings included:

* Informal sources rather than institutional service staff were preferred
* Despite that, social networking tools were largely underused
* Differences in information use between the seven research teams indicated that there is an uneven pattern of use between them
* Each participant or group grappled with the information problem in their own way - no common or universal information strategy was adopted. These were small science rather than big science (Price de S, 1953) in their approach
* They communicate their findings through conference proceedings and journal articles
* These practices bore little relationship with the policy-makers' strategies and their funding policies.

As reported in the study "Research funders and information providers must be informed by an understanding of the exigencies and practices of different research communities" to ensure scientific productivity and cost-effectiveness, and it should be recognised the differences not only between disciplines but also between research areas and even between similar research teams and individuals.

Summary of Professionals

Information about specific professionals' needs and use of STEM information is lacking in the public domain. A recommendation from this MPhil project is for key stakeholders to investigate the way STEM information generated in the academic world is transmitted to and within individual professional areas.

The trend appears to be a breakdown of protective barriers surrounding professions, and the opening up to more democratic participation from what has been traditionally a latent market for STEM material.

Better information about such trends will inform what package of information services would be appropriate for each target group, and how these could be delivered in future – what information infrastructure would be required. This would take into account the challenges facing the professions as society itself adapts to the new millennium as well as the environmental changes which affect the attitudes of the traditional society members, and the different procedures used by different disciplines.

The role of learned societies, as protective agencies for some professions, are important in this respect, and this issue is explored later in this thesis (Chapter 7).

5.5. SMALL AND MEDIUM ENTERPRISES

5.5.1. SMEs

Defined as private or public organisations with fewer than 250 employees (Ware, 2009b), SMEs represent a significant part of the industrial base of a developed/developing economy (ONS, 2014). They are often the source for new innovation which defines the direction society and the economy takes. They are frequently the pioneers, innovators, and entrepreneurs.

Many entrepreneurs base their operations on latest STEM developments. Their initial inspiration may have arisen from research which took place in academia, research institutes or large corporations. They may have assimilated the scientific ethic or culture from their past educational training. In this respect the needs of SMEs are similar to academics. Where they differ is not having ease of access to the latest STEM developments, as reported in scientific media, mainly through SMEs being faced with the current expensive business model for accessing STEM material.

The Professional versus Commercial Ethic

Also they are constrained from openly revealing the results of their own research for competitive reasons. SMEs operate under a commercially-focused profit-generating motive. As reported by Kornhauser, there is often conflict between the professional ethic of the researcher and organisational goals (Kornhauser, 1962). The researcher, within academia, has sought solutions which are usually open for universal benefit; within a corporate organisation this drive is transformed into benefits which need to meet the company's commercial requirements. There are also different hierarchical structures between academia and industry - the reliance on organisational authority as opposed to technical expertise and professional autonomy is an area of possible tension.

The incentives systems are also different - personal recognition for results achieved (scientific or professional ethic) versus financial rewards (commercial ethic). On one hand organisations attach more value to marketing, commercial and legal issues within which the company operates; on the other hand, there is the curiosity factor which motivates academic researchers. Whilst such conflicts may have greater visibility in large corporations, the difference between professional and organisational ethics resonates even within SMEs.

Organisational size

Though 250 employees are used as the upper limit for an SME or having a turnover of up to £36 million, a more realistic breakpoint would be small, energetic and entrepreneurial companies with fewer than 50 staff (defined as 'small' by the EC in recommendation 2003/361). Those with 50-249 are classed as medium-sized enterprises. Several statistical compilations also include a category of 'micro businesses', which are those with fewer than 10 employees (European Commission, 2003).

Table 5.5. Sizes of SMEs as defined by the EC

Company category	Employees	Turnover	Balance Sheet total
Medium-sized	<250	<Euros 50 mil	<Euros 43 mil
Small-sized	<50	<Euros 10 mil	<Euros 10 mil
Micro-sized	<10	<Euros 2mil	<Euros 2 mil

The actual number of SMEs is striking – according to Ware in 2006 there were 4.7 million companies in the UK of which 99.9% were SMEs (Ware, 2009b). Furthermore, 99.3% were businesses with fewer than 50 staff and this represented 59% of all private sector employment, and 37% of overall turnover.

Those companies having close to 250 are more likely to have sufficient financial resources to enable research to be conducted within their organisation under the panoply of support services, such as in-house research libraries, collection budgets, information support staff and IT services. This would make them analogous to larger R&D corporations and academic institutions in their research profile. For the purposes of this study, a 50 limit on employees would be a more pragmatic definition of an SME researcher.

5.5.2. Ware survey of SMEs

An analysis of SMEs information habits was made by UK consultant Ware (Ware, 2009b) on behalf of the Publishing Research Consortium (PRC).

In his study Ware focused on the information needs of SMEs with a high technology orientation and up to 250 employees. It was felt that a great majority of micro-businesses would have no interest in scientific or research publications. This assumption could be challenged given the increase in skilled innovators coming straight from higher education into industry (see section on Academics, 5.7). A proportion of these - those with of a strong innovative drive - could go into start-up businesses and self-employment. The attractions of self-employment and potential greater wealth compared with a tenured position could be a significant stimulus for dynamic entrepreneurs. There is insufficient UK data available to substantiate or challenge this hypothesis however. In the USA it appears from National Science Foundation data that companies with fewer than 100 employees employ 37% of graduates (NSF, 2014). On this basis, SME employees could represent a high proportion of graduates leaving academia to become innovators.

Mansfield attempted to measure the returns to R&D from those innovations that are sourced primarily from academic research. In a survey in 1991 of R&D executives in US firms, he found around 10% of new products and processes would not have emerged within a year without support from relevant academic research. These contributed to 3% of sales and 1% reduction in costs. By 1998 he found these percentages had increased to 5% of sales and 2% of cost reductions (Mansfield, 1998). The proportion of new products launched between 1986 and 1994 which depended on R&D varied between 5% and 31% depending on the business sector. Another commentator (Henry, 2007) claimed that SMEs made a major contribution to the commercialisation of emerging technologies, and that universities played a significant part in this process. 22% of SMEs attributed new product ideas to research undertaken within universities. Results from Germany gave 10% of innovations and 5% of new product sales being reliant on access to scientific information (Beise & Stahl, 1999). In Ware's study he concludes that "The survey findings make clear that there is a subset of SMEs for whom access to research literature is highly important to their success".

Ware also pointed out that barriers to accessing STEM information were greater among SMEs (fourth in terms of the list of barriers) than was the case with large corporations (where barriers to access ranked tenth). He points out that whilst access to journal articles was easy/fairly easy for 71% of SME respondents overall, this figure is less than for large corporations (82%) and universities (94%) who benefit from being 'affiliated'. A majority of SMEs (55%) have experienced difficulties in accessing an article. This is higher than that given by large companies (34%) and universities (24%). It is apparent that SMEs have greater difficulty accessing STEM than other information groups.

Nevertheless, SMEs attach high level of importance to research articles, putting them above other forms of reference publications in their need for access. This is in contrast to large corporate research centres which ranked technical information and standards specifications higher. However, the SME audience surveyed by Ware was selected on the basis of their being technical innovators, which could have biased the findings.

The Ware survey was based on subscribers to technical industrial/trade publications, STEM journal authors and individuals who had purchased articles by pay-per-view (PPV). 29,090 emails were sent out to this group and a total of 1,131 completed questionnaires were received (4% response rate). However, only 186 came from SMEs (and as pointed out, many of these would reflect more the affiliated community rather than the unaffiliated). The other responses came from large corporations (111), universities (470), and research institutes (363). So the working number of responses for the purposes of this study is a proportion of the 186 which are 'small' – only 98 responses came from organisations employing fewer than 25 staff.

Despite this, Ware's study has highlighted difficulties facing an information service geared to end users in the non-institutional sector. For SMEs these difficulties were:

- Perceived high prices for published information
- Need to review the full text even of irrelevant articles to assess their value (as a result of uninformative and misleading abstracts)

- The need to buy articles from a plethora of individual publisher web sites none of which adopt a standard approach even after Google, PubMedCentral, etc, had identified them as sources for the article.
- Several respondents claimed that company purchasing procedures stood in the way of easy acquisition of required articles.

Ware's research also indicated that, should these publisher-controlled features be addressed, then part of the long tail of SMEs could be brought into the scientific communication system.

SMEs in the Ware survey indicated that 5% of usage came from pay-per-view (PPV) which is a factor of five times greater than university or corporate usage. Almost one third of SMEs among Ware's respondents had used PPV at least once per month, compared with only 14% of large companies and 7% of academics. Smaller SMEs could be even more responsive to buying individual articles if a more acceptable pricing model were put in place. However, Ware's view was that "Pay per view is not currently a frequently-used channel and our interviews suggest that it has a number of unattractive features for users that are likely to limit its expansion in its present form". He also felt that the iTunes model of charging (see DeepDyve as a case study in the Appendix 3.1) had only slight chance of success. However, his report was written over five years ago since when elements of the 'perfect storm' and other changes (see sections 5.9 and 6.4) will have altered perceptions about STEM within the SME sector.

Of interest was Ware's suggestion that learned societies could increase their library functions to help with access for its members who are currently within the SME sector, but this was a suggested option for improvement rather than a quantified primary recommendation. This issue, and others related to learned societies, is explored in chapter 7.

5.5.3. UK enterprises

According to the UK Office for National Statistics there were 2.10 million enterprises registered for VAT and/or PAYE in March 2010 (ONS, 2011) – fewer than the figure used by Ware. The professional, scientific and technical sector accounts for the largest number of businesses, with 15.4% of all enterprises registered which amounts to over 300,000 STEM-related organisations in UK private industry.

The distribution of enterprises by employment size band shows that 88.6% of all companies employed fewer than 10, and 98.0% had fewer than 50 employed. Large enterprises, those with 250 or greater employment, accounted for only 0.4% of registered enterprises. These proportions are in line with Ware's data.

Innovative business strategies to promote availability of research literature to this large group of corporations in more diverse ways is required. There is a 'long tail' of companies which are currently of such a small scale that they would fall outside budgets for research publications.

Support for SMEs came from David Willetts (Willetts, 2013), then UK minister for universities and science, who claimed "Every year the government spends almost £5 billion on science and research. Yet the results of that research are generally behind paywalls that individuals and small companies cannot afford, even though they have paid for that research through their taxes" (Willetts, 2013, paras 2-3). These figures were used for the government's alternative publishing proposal, one which heralded 'free at the point of usage' or open access.

To many independent observers it was unfortunate that this led to support being given (in the Finch Report, see RIN, 2012) to a Gold open access system – a system which allows commercial control to remain with journal publishers. Under the Gold open access business model (see section 6.2.5.1) the traditional barriers created through authentication control (subscription and licensing) would be swept aside, and instead publishers would impose article processing charges (APCs) which authors would be required to pay. These can vary from $100 to $3,000 per article (Solomon, 2012). Many considered that Finch's support for this business model was dictated by the powerful STEM publishing lobby. It gave STEM publishers a revenue-generating lifeline. The alternative of supporting a Green open access model, which would favour the library community, received only limited support in the report.

There appeared an intent within the Finch group to ensure that existing STEM institutions and structures should be bolstered and protected. This defies the gravity of market forces, when new, more efficient and acceptable services lead to the demise of out-of-date and dysfunctional operations. If the evidence is that commercial journal publishing and collection development within research libraries have run their courses then it seems commercially irresponsible to promote questionable or outdated business models to protect them.

5.5.4. Management consultancies

Support for corporations, including SMEs, seeking to resolve specific operational or strategic issues has been provided by management consultancies, a relatively new profession. However it is a profession which has seen the impact of changing access to research information at close quarters. The traditional portfolio of services offered by consultants included using access to external data to generate detailed reports - in some cases for SMEs and also including STEM material.

Now access to this source information is open to all, including consultancies' former clients, through the Internet. This changes the profile of support services being offered by management consultancies. The decline of consultancy services (producing bespoke reports for clients) has been overtaken by the Internet and open information, whereas the research-only consultancies (Forrester, IDC, Gartner) have remained largely immune from such trends.

A development which relies on social, technical and commercial aspects has arisen from the recent trend towards crowd-sourcing of advice. There is a mechanism for industrial enterprises to get answers to R&D questions through services such as InnoCentive, OPenIDEO and Wikistrat. These services bring together in a virtual network the world's smart people who compete to provide ideas and solutions on topical business, social, policy, scientific and technical challenges. There is a network of millions of problem solvers, proven challenge methodology, and cloud-based technology which combine to help transform the economics of innovation. Included within such a network could be SMEs – they are not excluded as a result of any commercial barriers - as both users and contributors to such services.

Participating companies post 'Challenges' – scientific problems – which anyone can respond to, with the prospect of being paid for providing a solution. Connections made by these services are between parties who would otherwise have only met accidentally. "The attention of the right expert at the right time is often the single most valuable resource one can have in creative problem solving" (Nielsen, 2011). This collaboration has been defined by Udell as 'Designed Serendipity'. Designed serendipity occurs when intractable problems facing a scientist are unlocked as a result of finding the right expert at the right time to help. That person can be anywhere in the world. It opens up the potential for the amateur, the interested bystander and the educated public to become involved in scientific discourse which has traditionally been the preserve of the dedicated and highly trained scientists in academia/industry. There is just as much scope for creative solutions to come from the enfranchised knowledge worker; ideas and solutions are not the sole preserve of academia and large-scale corporate R&D. This process is democracy at work in the industrial world, one which does not preclude members of SMEs or UKWs from taking part.

For more than a decade, leading commercial, government and non-profit organisations such as the AARP Foundation, Booz Allen Hamilton, Cleveland Clinic, Eli Lilly & Company, EMC Corporation, NASA, Nature Publishing Group, Procter & Gamble, Syngenta, The Economist, and The Rockefeller Foundation have partnered with InnoCentive, etc, to generate new ideas and solve problems.

There is also scope for SMEs to bypass consultancies in future by incorporating information technology services in-house. They can enrich their innovative activities without relying on expensive external services. Particularly when they take control over data which they have under their command, such as analysing the 'data exhaust' left by users of their services, or using free Internet and digital sources. Developments in artificial intelligence and cognitive computing will give greater power to a wider universe of small organisations to support innovative services in an innovative way.

Summary of SMEs

Many researchers exist in companies which have few employees but nevertheless rely on access to latest research results to become competitive and innovative. As individual researchers they face a cultural challenge in moving from a sector where increased openness and sharing of results - academia - to one where products, markets and profits dictate success criteria. There are a large number of SMEs in the UK and as the economy depends on their productivity, increased attention and public funding on supporting them is occurring at grass-roots level. As an outlet for a better STEM information system they are an important sector. Particularly as the Internet opens up new resources which they can tap into and which can be used in tandem with greater accessibility to STEM data.

5.6. CITIZEN SCIENTISTS

Researchers and academics share data and research results across web-based platforms so that the global scientific community can benefit and build on scientific datasets through widespread collaboration and interaction. One example of this collaboration is the data generated for climate change and developed using global-scale models (Cooney, 2012). There are several such international, cross discipline collaborations which support a wide circle of participation from the community at large.

Methodology

There is much in the trade literature and online media (from newspapers through to TV programmes and social networks) which refer to the increasing involvement by individuals who have an interest in becoming part of national and international research projects. This section is based on an analysis of commentaries in these general and trade sources.

Using informal sources involves departing from reliance solely on primary refereed published material as included in the literature review (particularly books and journal articles), as well as departing from the data-based statistical sources used in analysing demographic trends (see section 5.10). The approach involved selecting information from across a spectrum of platforms – formal, informal, social and anecdotal; primary, secondary and tertiary – and assessing each in turn. This analysis of an extensive platform of publication systems has been a key feature of this section on citizen scientists. Provenance of the sources was critical in making judgements as to the item's relevance. Each source item was evaluated for its content, origin and relevance in relation to the aims of this thesis.

The process then included relating the items to other commentaries. This enabled an integrated picture to be developed.

5.6.1. Citizen or Amateur scientists

The Wikipedia entry for Citizen Science includes:

> "Citizen science is a term used for projects or ongoing program of scientific work in which individual volunteers or networks of volunteers, many of whom may have no specific scientific training, perform or manage research-related tasks such as observation, measurement or computation" (source: Citizen Science entry in Wikipedia).

Citizen science refers to the public engagement of citizens who actively engage with scientific research, such as by inputting experimental data for researchers, or analysing data elements. This highlights an opening up of science, making it more democratic and less hidden behind impenetrable procedures, terminology and traditions. It represents a coming together of science, policy and society.

As UK society benefits from access to higher education attendance rates (see chapter 5.7.4), the scope for individuals to pursue interests, which may or may not be directly relevant to their chosen career path, increases. There is a demographic stimulus to citizen science and its participation in the research effort.

At the same time, enhanced information infrastructures support many new social networks and informal online groups which enable common interests to be shared. Social networking leads to social collaboration. The stimulus is towards exploring new frontiers, expanding the mind, feeling comfortable with the environment within which they exist, and 'belonging' to a kindred group. They offer awareness and understanding of scientific and technical issues relating to their specific areas of interest, and ride on the back of popularity of social networking for their inter-community interaction and communication.

There are many examples of social collaborations, from studying the distant universes in astronomy through to elimination of poverty and starvation – from protecting the environment to monitoring weather patterns – from studying biodiversity to understanding how to control diseases. Advancing their commitment in supporting their particular scientific interests requires ease of access to relevant research results.

The difficulty is that the structure of the scientific communication process, with its use of licences restricting use only to individuals affiliated to subscribing institutions, creates barriers in pursuing such interests by citizen scientists. They are unable to avail themselves of latest developments in their areas of interest. Yet they represent growing and in some cases powerful interest groups. A feature of the new digital consumer is greater propensity to participate online in ways which were unusual or impossible in traditional print mode.

5.6.2. Examples of citizen science projects

Increasing numbers of international research projects rely for their success on participation from citizen scientist. An example is SDSS or the Sloan Digital Sky Survey (SDSS). Volunteers are given access to digital photographs of galaxies and asked questions such as 'is this a spiral or elliptical galaxy?' and 'if this is a spiral, do the arms rotate clockwise of anticlockwise?' Classification of the galaxies is still done better manually than by computers. SDSS (http://cas.sdss.org/dr5/en/) contains approximately three terabytes data provided by 13 institutions with 500 attributes for each of the 300 million 'objects' – all freely available online. In effect it is a prototype public domain operating a virtual e-Science laboratory in astronomy. In total there are no more than 10,000 professional astronomers worldwide; however, there are more than 200,000 who participate in this so-called Galaxy Zoo classification and over 930,000 users. The site is specifically designed for public participation and use.

Online tools are also changing the relationship between science and society in other areas. The Human Genome project and its derivatives such as Hapotype collect data on human genetics. The eBird service relies on local input from approximately 2,500 volunteers who monitor bird populations and migrations. The National Audubon Society Christmas Bird Count has taken place annually for over 100 years. There is also an Open Dinosaur Project which helps understand how dinosaurs evolved. A strong link exists between 'cloud-sourcing' as a way of conducting research and participation by global networks of citizen scientists. Each project has its own tools, procedures and forms of collaboration.

Collaborative citizen science projects also exist in areas such as monitoring the earth's atmosphere and earth's surface, feeding data into a central repository about the earth's climate. Other examples include collaboration in shaping proteins within DNA. 75,000 participate in this which has become as much an entertainment as leading to important research findings in biomedicine. In several domains citizen science has a long history - for example, the Victorian naturalists and in areas of ornithology, in meteorology and archaeology, where an emphasis on observational recording is central to scholarship. Projects such as Wikipedia and SETI turn to volunteers for input. Through Folding@home, 40,000 PlayStation 3 volunteers help Stanford scientists fold proteins. In ReCAPTCHA, amateurs help digitise *The New York Times*' back catalogue. In the ESP project, the public has labelled 50 million photographs to train computers to think. In Africa@home, volunteers study satellite images of Africa, to help the University of Geneva create useful modern maps. Conservation biology, a vast academic field, depends on amateur surveys, both outdoors and in historical collections. At Herbaria@home, volunteers decipher herbaria held in British museums.

These are serious scientific projects where large groups of volunteers focus on scientific problems which are beyond the reach of small groups of experts and individuals. There is resurgence in citizen science as the Web influences in a positive way how science can be performed.

5.6.3. Networks of science collaborations

Additional aspects of collaborative networking can be found in unlikely areas. In 1999 world chess champion Kasparov played a game of chess against 'the World', with the world drawing on the input from 75,000 chess-addicted individuals from 75 countries who attempted to beat the champion by voting, by consensus, on what should be the next move. In the end Kasparov won, but it was a close fought game and highlighted the power of the 'wisdom of the crowd' (see section 6.4.2.3) in doing something which no individual chess player could have achieved working on their own. The best of each individual's participation was aggregated to create a powerful force. It was a force of amateurs, of citizen scientists, who were just as competent in aggregate as the world's leading chess expert.

There is a cautionary note to add. Whilst the wisdom of the crowd of citizen scientists endorses the importance of their scientific role, a parallel development in the computer world gives just as much credence to computers and artificial intelligence in providing solutions to scientific problems. For example, IBM's Big Blue computer system competed with Kasparov in a similar chess challenge to the one above, and in this instance the computer won. There are tasks which citizen scientists can take on as a community, and tasks which artificial intelligence (AI) is better at. The power of AI and cognitive developments is only now beginning to challenge the human mind in offering greater efficiency in many routine activities (Greenfield, 2014).

Meanwhile, the collaboration of minds still has resonance. In 2009 a Cambridge-based mathematician, Sir Tim Gowers, created a networked approach to solving stubborn mathematical problems. He used his blog to invite readers to solve a challenge which became known as the Polymath Project (Gowers, 2009). After a slow start the participation of mathematicians from around the world exploded as mathematicians having all levels of expertise came up with a solution. After 37 days of open collaboration it was claimed that not only had the original problem been solved but also a broader and harder problem had also been answered. Such massively collaborative activity has become a powerful new way of attacking difficult mathematical problems.

These and other similar projects combine the expertise and experience from recognised world experts to humble citizens. Collectively they have a common focus, and the resulting network of collaboration benefits from multi levels of expertise - academic and practical - all having demand for equal access to relevant research ideas and published research data.

Citizen science projects take on a new dimension as and when they become linked, and the data resources of all the projects become cross searchable. This is the concept of Data Web, which gives Artificial Intelligence or Cognitive Computing a new stimulus. The interaction between Data Webs and Artificial Intelligence is data driven intelligence (Neilsen, 2011) and is growing rapidly. It highlights new ways of finding meaning which are different from an entirely human, manual approach and more in line with capitalising on the strengths of the combined resources of the computer and the human mind.

This is because research data is increasingly being generated by large computer systems, with the resulting data requiring human analyses which is still beyond the capabilities of computers (particularly relevant in astronomy which requires human classification of galaxy images, as described above). It results in new disciplines being created which are conjoins of established disciplines – such as bioinformatics (computers with biosciences); cheminformatics; astroinformatics, etc. Many of these include individuals outside the mainstream of academic based research, yet they would benefit from access to relevant research output, as well as providing input into research projects. The web of interested participants in the scientific effort increases.

In Weinberger's book "Too Big to Know: Rethinking Knowledge", the author says:

> "...the change in the infrastructure of knowledge is altering knowledge's shape and nature. As knowledge becomes networked, the smartest person in the room isn't the person standing at the front lecturing us, and isn't the collective wisdom of those in the room. The smartest person in the room is the room itself: the network that joins the people and ideas in the room and connects to those outside it" (Weinberger, 2012).

Given the wide range of projects which tap into the hive mind of citizen scientists, is the attention span and commitment of current citizen scientists likely to taper off and decline? If one takes the Galaxy Zoo projects with its 200,000 participants, using gross estimates of the sum of individual's time commitment one arrives at an annual full time equivalent of a team of 250 people. As Americans spend as much as 5 hours per day watching television, this amounts to 500 billion hours of TV watching (Pew Research, 2012). This suggests there is scope for citizen science to expand in future if the (latency in the TV resource) can be captured and the social interest (of citizen scientists) organised and activated. This is the point made by Shirky in his 'cognitive surplus' which is a feature of an increasingly educated society (Shirky, 2010). It explodes the traditional Dunbar concept (that the average person has 150 contacts, see 5.9.2.2) by enabling 'friends' and social networks to extend the platform of active STEM participation to thousands of individuals.

To quote Nielsen (2011) “We’re seeing a great flowering of citizen science”. He goes on to speculate that “will we one day see Nobel Prizes won by huge collaborations dominated by amateurs?” - such is the pace and extent of the collaborations by amateurs in scientific progress.

Summary of Citizen Scientists

Citizen science may work best in areas where there is a need for community action. They could be built around virtual seminars and conferences, online question-and-answer sessions, discussions groups, etc. Nor does one have to be an academic to qualify to become part of such a community. Many people are smart, and as long as they have the interest and commitment, and as long as there are tools are available, and as long as they have a specialist expertise, they could become active citizen scientists.

In a more open and democratic research world the refereed research paper, the mainstay of current STEM publishing, is only of partial relevance. More important is individual commitment and systemic easy communication. Application of AI and cognitive computing technologies need to be factored into the growing social participation in STEM research. Overall, citizen scientists need a formal, transparent and interactive information support structure which is currently more evident in the breach than the observance.

There are many scientific experiments - citizens are able to access and contribute to scientific Big Data in real time across virtual platforms and thereby influence scientific progress, and sometimes, government decision-making processes that affect daily lives. This alters the structure of the research process, rendering it less exclusive and more inclusive of a broader spectrum of researchers and knowledge workers within society.

5.7. ACADEMICS

Though academics are not at the forefront of being UKWs, there are instances where they are also disenfranchised from accessing STEM material - they are similar to UKWs in their need for a more effective STEM information system.

Academics are subject to access barriers. These come in several commercial, legal and administrative forms. Should they be successfully overcome, affiliated academics could also benefit from the way STEM results could be made available in future. Therefore, an analysis of the academic sector, and its relations with UKWs, is an appropriate topic for this thesis.

Methodology

The emphasis in this section moves from a qualitative to a balanced quantitative and qualitative analysis. Though quantitative research is usually linear in its progression, in the following there will be a mixed methods (MMR) approach which combines both opinions and data.

The approach is to integrate several datasets from different sources which quantifies the 'affiliated' academic community. The data is primarily from UK national public sources. There is a constraint in that definition of the variables – disciplines, research areas, professions, knowledge workers – is not consistent between agencies. Data used for categories by one government agency, such as Office of National Statistics, does not sit well with data for similar categories from UK Department of Business, Innovation and Skills, or the Higher Education Statistics Agency. This thesis comments on this noise.

Combined with the other demographic sectors, academics could be galvanised into making research information more open and democratic in future. Much depends on the stability of the organisations to which academics are attached on whether academics will be drawn into effecting change to STEM. The future of universities as institutions is therefore an important consideration.

5.7.1. Mission of universities

Universities face a challenging future. There are five main areas in which problems may arise.

- *Competition.* Competition for students is growing as universities and governments face austerity. The issue of student fees and their expectations (for example, in ease-of-access to a fully comprehensive selection of STEM material as a right) could become a troublesome area.
- *Digital technology*. New electronic systems are being introduced to offer online education which changes the physical boundaries for academic teaching. Teaching needs no longer be done in a central space. Face-to-face teaching/education methods could be replaced with new digital e-learning systems (such as Massive Open Online Courses, or MOOCs) or personalised interactive learning services operated by commercial organisations.
- *Globalisation*. Both teaching and research are becoming more international. This increases cross border collaboration and information exchange. It also supports emergence of international 'centres of excellence' which trade on their brands and image at the expense of universities having less of a reputation
- *Democratisation*. The amount of knowledge available online, the different formats it takes, and the ease of adding to and accessing it through open access (OA) systems, changes the elitist nature of universities, and makes information open to all and more democratic.
- *Industry.* Increasing partnerships between universities and industry are exploiting research output from universities. The exclusivity of academia at the heart of a nation's research effort is challenged.

These developments raise questions about the viability of universities which rely on revenues from traditional teaching and research services. Several smaller universities could face closure, whereas the scope for new commercial entrants particularly in the online education sector to take over (digital) teaching roles is a possibility.

In a study by Ernst and Young on Australian universities, the consultants identified three possible courses of action (Ernst and Young, 2012). The first is for the university to maintain a 'streamlined status quo' by which universities would improve their interaction with the community at large – which could include offering services to UKWs. The second is to become ‘niche dominators’, targeting a particular customer segment with tailored education and research services. Again, universities could extend their reach into communities beyond the campus. The third is for universities to become ‘transformers’ enabling private initiatives to work with universities to carve out new roles for themselves. This again suggests a more open and democratic approach within academia, embracing UKWs along the way.

Failure by universities to tackle disruptive technologies would open the door for a tech-enabled quality on-line education system that can be accessed by anyone, anywhere with an Internet connection. Today’s online education is far more advanced than earlier distance learning services through the use of technologies such as cloud computing, at-scale video distribution, social networking and artificial intelligence. If higher education changes what role is there for those universities which have limited research activity?

5.7.2. Academia

In essence the university will no longer rest on past laurels or remain isolationist but will need to adapt to emerging technology and market conditions. Indications of new approaches in their research activities are seen in the strengthened relationship between private and public sectors. Spin-offs from universities, such as Ingenta emerging from BIDS, and CIBER from UCL, are examples. Other examples include Lycos, Crucell and Genentech. The isolationism of universities will decline in favour of greater partnerships and collaborations with private industry. Elitism will give way to greater democracy.

Greater democracy and openness is advantageous for knowledge workers who could become involved in this broader collaboration. It dovetails with the emergence of open innovation, of global collaboratories and projects. The central idea behind open innovation is that in a world of widely distributed knowledge and information, institutions cannot rely exclusively on their own local research expertise, but instead cooperate with other organisations whose expertise offer a different perspective.

On the other hand, there is a countervailing force which suggests that research will be concentrated in those universities that demonstrate excellence and impact. Brand, achievements, reputation and image are important for those few centres which can prove their high global status. This goes against the idea of there being less exclusivity and more democratisation within academia.

Universities are nevertheless under pressure to justify expenses and articulate the value of the education and research services they provide. There has been a rise in productivity and impact measurements, such as the h-index, and emergence of companies such as Academic Analytics (www.academicanalytics.com) that enable universities to benchmark their achievements against their peers, identify strengths and weaknesses, monitor performance, allocate resources and highlight their competitiveness.

There has also been the rise of university dashboards that offer analysis of such issues as recruitment, admission, graduation rates, time to degree, academic performance, financial support, student to faculty ratios, etc. As imperfect as these measurements might be they indicate an increasing reliance by each university on quantitative data to demonstrate their competitive net worth.

As indicated above in Methodology, it could be asked whether this analysis of the role of universities fits in with a study looking at the challenges facing unaffiliated knowledge workers. The response is that the strengths and weaknesses of universities is a factor in determining the direction which research and researchers (both affiliated and unaffiliated) take. Universities face similar troubling conditions as UKWs even though their starting points may differ. The jury is still out on how changing missions and roles of the universities will change the structure of higher education in the UK, or how it will impact on STEM communication. Irrespective of the outcome of this debate, the UKW-access issue from and by universities warrants highlighting. In particular, how they adapt to increased openess and democratisation of research processes at the expense of focusing on their insularity and uniqueness.

5.7.3. Academic researchers

The estimated number of academic researchers (as opposed to academics) worldwide grew from about 4 million in 1995 to 5.8 million in 2002, and approximately 6.4 million in 2007. In the latest Unesco Science Report (Unesco, 2015) the numbers of scientists worldwide is estimated at 7.3 million for 2011 and

7.76 million for 2013, which was an increase of more than 20% from 2007. The European Union has most researchers (22% of the world share), followed by China (19%) and USA (17%). See Unesco, 2010 and Unesco, 2015.

Data on researchers also comes from the OECD. In their 'Main Science and technology Indicators Vol 2014/2' (OECD, 2015) the following information on key countries is provided.

Table 5.6. Researchers in a selection of OECD countries, 2011-2013

Country	Total researchers	R&D full time equivalent	% of gdp on R&D from HEIs
Australia	92,649	137,489	28.1%
Canada	156,550	223,930	38.9%
Denmark	40,858	58,530	31.8%
Finland	39,196	52,972	21.5%
France	265,177	420,588	20.7%
Germany	360,900	604,600	17.5%
Israel	63,728	77,281	14.1%
Italy	117,973	252,648	28.2%
Japan	660,489	865,523	13.5%
Netherlands	72,325	121,496	31.8%
Switzerland	35,950	75,476	28.1%
UK	259,347	362,061	26.3%
USA	1,252,948	X	13.8%

Source: OECD, 2015 "Main Science and Technology Indicators Vol 2014/2" Tables 7 and 9.

The above figures for the UK indicate that over one quarter of R&D is being channelled through higher education institutes. They also indicate that a STEM communication system focused on the academic sector misses out on the 75% of research being undertaken outside academia.

The National Science Foundation gives statistics on the US information and research scenes (NSF, 2014). However, there is a question about what is defined as a 'researcher' in the NSF data (and by extension, the data from Unesco and OECD). The science and engineering workforce could be defined according to workers in S&E occupations, by holders of S&E degrees, and/or by the use of S&E technical expertise at the work desk. In 2010 the size of the S&E workforce in the US ranged from approximately 5 million to more than 19 million depending on which of the above definitions is applied.

Based on NSF data there were 12.9 million people in the US that said that their job requires a science or engineering degree (NSF, 2014). Grossing this figure up to achieve a global estimate, there are according to Price 51.6 million scientists and engineers worldwide. Of this figure, 6.8 million are teaching personnel at universities, and 44.8 million are in the private sector (Price R, 2011). This implies that the 'core' of academics is 12% of the total, and the 'tail' is 88%.

Furthermore, according to Price, founder of Academia.edu, in his blog dated November 2011, he estimated that the number of academics and graduate students worldwide was 10.8 million. His global approximations are based on data from the United States (NSF, 2006) and grossed up accordingly (Price R, 2011).

5.7.4. UK academics

The UK share of publications is above its human resource share of research; in 2002 the UK contributed 8.3% to the world total output of research publications, but by 2007 this share had fallen (largely in response to the awakening of the Far East economies and their commitment to research and publishing) to 7.2%. In terms of R&D investment per researcher the UK falls behind the United States, Korea, France, Germany and South Africa (Unesco Science Report 2010, p 12)

In the UK there are 162 higher education institutes. The number of students placed by UCAS in higher education has exceeded half a million (see UCAS' End of Cycle Report, December 2014). 512,400 students secured places in UK universities and colleges, up nearly 17,000 on 2013 (+3.4%) in 2013. More UK students than ever were accepted into UK HE (447,500, +3.2%) alongside record numbers of students from outside the UK.

40% of all students are studying in the hard sciences, with 60% if the softer sciences. This is relevant in apportioning the feed from post-academia into the UKW sectors according to subject orientation. For example, though the student population in the UK is approximately 2.3 million, fewer than 1 million (957,000 in 2010/11) were in STEM-related subject areas.

From this 1 million STEM students/graduates, less than 200,000 will remain in academia, and 800,000 will move into STEM related private industry and public services. There is a 'fire hose' of STEM graduates increasing the numbers of science-aware people within society. This sets the context for a greater understanding, and in some instances, greater demand, for STEM information within society.

In terms of researchers, the amount of research undertaken in universities compared with that undertaken in the private/business sector shows that there is still a heavy concentration within UK academia. 62% of the 262,000 researchers which existed in the UK in 2011 were in the university sector, compared with 33% in the business sector (the remainder being in government departments or classified as 'other'). See Elsevier, 2013. However, there is a gradient of so-called 'researchers' with a long tail of the occasional user of STEM material existing in the business sector.

These demographics are a powerful force increasing the pressure for the STEM information system to be changed to accommodate the growing awareness and appreciation of science within society. UKWs would stand to benefit from this trend.

5.8. THE GENERAL PUBLIC

Methodology

This section distinguishes itself from the citizen science groups in not focusing on a major local, national or global research project. The needs by the general public are more universal, less specific. As such the STEM information requirement is broader and more general, less specialised.

The approach taken is similar to that adopted for citizen scientists. A selection of material from a wide collection of primary and secondary published sources has been made. A combination of descriptive texts as well as some instances of quantitative data has been collected and analysed. The credentials of the sources has been evaluated, and the content of each identified item has been made to assess relevance, provenance and accuracy.

5.8.1. Democratisation of scientific research

As UK society benefits from greater attendance rates in higher education, and this increases the supply of qualified professionals, traditional elitism within academia is challenged. According to the Office of National Statistics (ONS, 2014), 27.2% of the UK population in the age range 16 to 74 years and 26% of UK jobs specifically require a degree. In the managerial, professional and associate professional employment categories the proportion of graduates rises to 43.6%. The proportion of the general public which has become science-aware is on the increase (see above section on Academics).

Knowledge flows are shifting. Traditionally it was top to down. Now it is increasingly both ways, with the general public feeding into the knowledge base just as much as extracting from it. It is also becoming less specialist and academic to becoming multi-directional with information being shared freely within and between organisations, academia and the public. New commercial paradigms and consumer-adapted services support wider, diverse and more numerous communities which can benefit from access to specialised research results.

Innovation is spurred by encouraging non-specialists to think openly and share ideas with specialists - translating their practical experiences and visions, in combination with drawing on academic excellence, into improving the effectiveness of the overall research effort. The value generated from research is multiplied within society as more people are able to access and make use of it in a variety of ways (the 'multiplier effect', see 6.4.5).

In January 2012 the BBC presented a TV programme entitled 'Stargazing'. It attracted an audience of over a million viewers. This demonstrated the breadth of interest in such a scientific topic, a level of interest which is not reflected in the uptake of learned journal subscriptions, or graduate enrolments, or individual article supply is in this area. Exemplars such as BBC SpringWatch, eBird63, BBC LabUK Initiative62 and Bioblitz Bristol have brought Web and mobile technologies together in engaging the public to collect natural history data and monitor species. These are more popular projects, as distinct from the specialised projects with which citizen scientists are engaged.

World famine, meteorology, poverty, environmental concerns, global warming and pollution – these social problems have inspired many individuals to research, investigate and comment on such issues, often without easy access to research results which could provide support for their background knowledge and understanding. The formation of the Citizen Cyberscience Centre, a collaboration between CERN, UNITAR and UNIGE, reflects the importance of this approach, particularly for international collaboration, among developing countries and for neglected diseases. It indicates that the move towards 'democratised science' is not confined to a few select areas – it has a broad base particularly in environmental areas.

5.8.2. Science and the media

Besides not being able to access all research results freely, there is a further challenge facing the general public in preventing them from getting accurate interpretations of research results. This is when science news is reported in magazines or newspapers. It is often questionable whether scientific reporting is accurate or whether it is biased and comes with the writer's (or publisher's) agenda.

As an example, Sir Paul Nurse, Director of the then UK Centre for Medical Research and Innovation (UKCMRI) and President of the Royal Society, presented a programme for Horizon in January 2011 in which he felt that scientists had not done well in getting the message over about the results of their research. Instead, the results were often cherry-picked by the righteous zealots in order to hijack the true message from the research purely for public consumption (or to sell newspaper copy) (Nurse P, 2011).

Though healthy scepticism of research results is laudable – particularly over issues such as global warming or genetically modified crops – the alternative position of obstructive denial is neither good for innovation nor for social progress. It has become a case that 'a point of view is adopted rather than peer review', and those who do not follow peer reviewed publications in detail are left to make interpretation on interpretations. There is, according to Nurse, the need for the conspiracy theorists and the peer review community to be brought together, and for the public not to be fed with conflicting and hysterical messages through the media (Nurse P, 2011).

Scientists are not good at managing the media message. Nor are publishers in delivering a balanced message to the public. Free and open access to data means that scientists are not the only interpreters of research results. Anyone can have their say, however poorly considered and whatever the knowledge base of the author/commentator. This concern about misrepresentation of messages is referred to by Andrew Keen (Keen, 2007) who lamented about the growth of the 'culture of amateurs' and the noise which such a fully open and democratic scientific information system produces (see section 6.4.2.4). This concern is heightened by the uncensored outpouring of blogs and wikis which operate in a world parallel with formal scholarship (Horrigan, 2006)

In the February 5th 2009 issue of *The Guardian*, Andrew Brown wrote a critique of the STEM publishing system (Brown A, 2009). He tackled the issue of the closed system of publishing for scientific research, with high priced journals dominating the scene. One answer to this, claims Brown, is to promote the growth of free scientific publishing, and greater sharing of the immense quantities of data that lie behind most published papers. However, there is a problem with open access for formal publications - for those who really want to know what is going on, open access is not yet sufficiently widespread. There is no guarantee that interesting work will appear in open access journals. Also, open-access journals are written to be informative in particular fields of specialist study - for the specialists - and not for the general public.

Nature and *Science* are exceptions in that they often include an item at the front of the magazine explaining in intelligent layman's terms what is described in the paper and why it matters. More such quality assessments of research and interpretations for a lay audience may be required in formats and at a price acceptable to a wider community (see section 6.6.1).

5.8.3. Science and the general public

Much of crowd-sourcing, or mass voluntary participation, is just ‘grunt work’. It is basic lab-assistant-type activity that often deals with image recognition and can be readily undertaken by the general public. Scholars engage less with the ‘hive mind’ - the public - when it comes to more complex or interpretative work. This is where citizen scientists may have a greater role. Nevertheless, both the general public and citizen science have comparable interests in science, and their demarcation as groups or communities is fluid and variable.

STEM publishers rarely made public their ‘core’ research publications - though there are occasional instances where items are made freely available for PR purposes. Members of the general public only have to try accessing the research results via Google instead of through a university account to experience the extent of information rejection. Many STEM publishers make clear that they are commercially owned and prevent access to all those who have not paid for right of access, either directly or through a licensing agreement, in order for their organisations to survive financially. It is equally problematic that JSTOR, the database of most twentieth-century scientific articles in the social sciences and humanities, is off-limits to the public because of publisher-protected copyright laws. The suicide at 27 years of age of the computer wizard Aaran Schwarz in September 2013, author of RSS and Reddit systems, after being sued for downloading articles from JSTOR, is a particular tragic consequence of a publisher-erected licensing barrier facing individuals (Day, 2013).

How will STEM publishers in future meet the challenge of providing an increasingly interested public with access to publications which the general public’s taxes have often been responsible for creating? If the system changes to accommodate a wider circulation of what is currently ‘closed’ information, then the existing attractive business model for publishers needs to be revised. However, in doing this there is no guarantee that future margins and profits will be at the same level as now.

As Murray-Rust (Reader at Cambridge University) described in a listserv message (LibLicence on 30 April 2012):

> “The idea that there is a set of "researchers" in Universities who deserve special consideration and for whom public funds must be spent is

> offensive. I fall directly into SH (Stevan Harnad's)'s category of "the general public", whom he now identifies as of peripheral importance and thankful for the crumbs that fall from his approach. I have worked in industry, work with industry and although I have been an academic am not now paid as one. The idea that I am de facto second-class is unacceptable.
>
> "There are no areas of science and more generally scholarship which are not in principle highly valuable to "the general public". I am, for example, at present working in phylogenetics - not a discipline [in which] I have been trained".
>
> (Murray Rust, 2012a)

Murray-Rust is a supporter of publicly funded Gold open access and of Green repositories which allow free access to published information. He is not prepared for these to be dismissed *ex cathedra*. Both work well in the areas he is acquainted with – he is on the board of PubMedCentral and also on the board of an Open Access journal (where, he claims, half the papers come from outside academia and are every bit as competent and valuable as those written by academics). Murray-Rust would like to see effort focused on information-saving and sharing tools that people need – all people, not just the academics and knowledge workers.

It is notable that uptake of publication-related tools such as *Figshare, Dryad, Mendeley*, etc. is high, because people actually want them. The Internet provides opportunity to use tools and services to become more involved than in the past. No expensive equipment is needed – just a home computer or smartphone. Entry barriers to communicate about science have dropped. These are people who belong to the unaffiliated knowledge worker (UKW) and general public communities. Their eyes have been opened, and they are champions of a new global collaborative network which operate with different rules of participation.

5.8.4. Engaging with the wider community

There is no single approach which governs the way the scientific community acts. “There is no dictator determining the patterns of behaviour that make up the scientific community. But out of the actions and relationships of millions of individuals certain regularities emerge. Once those habits arise then future individuals adopt them unconsciously” (Brooks, 2012).

Publishing a lay summary alongside every research article could be the answer to sharing a wider understanding of health-related information, say the findings of citizen science project in the UK entitled Patients Participate! Commissioned by Jisc and carried out by the Association of Medical Research Charities, the British Library and UKOLN. Patients Participate! asked patients, the public, medical research charities and the research community, ‘How can we work together in making sense of scientific literature, to truly open up research findings for everyone who is interested?’ The answer came from patients who claim that they want easy-to-understand, evidence-based information relating to biomedical and health research.
(http://www.jisc.ac.uk/whatwedo/programmes/digitisation/econtents11.aspx)

Every day people are bombarded by health news, advice columns, medical websites and health products. Making sense of all this information is difficult. Tracey Brown, Director of Sense about Science, says, "We have been working with scientists and the public for some years to challenge misinformation, whether about the age of the earth, the causes of cancer, wifi radiation or homoeopathy for malaria. It is often very effective but no sooner is attention turned elsewhere then misleading claims creep back up again. To make a permanent difference, we need the public to be evidence hunters. We are delighted to encourage patients to engage with the evidence for medical claims." (Brown T, 2014).

Alastair Dunning, digitisation programme manager at Jisc, has also pointed out that, "Jisc believes that publicly-funded research should be made available for everyone and be easy to find. We have funded work to show how making access to scientific literature enables citizen-patients participate in the research process, therefore providing mutual understanding and better links between scientists, medics, patients and the general public". Jisc’s programme to support an open scholarly information system is a powerful agent for change in favour of a democratic system within which non-academic communities could also participate.

5.8.5. The British Library and UKWs

BL Direct is a document delivery service enabling individuals from all sectors to buy articles online using their credit cards (after registration of their profile). BL Direct requires an online payment to be made which covers not only the costs of accessing the article from the British Library at Boston Spa, but also the copyright fee agreed with the publisher. The catalogue of items included is based on BL's ETOC (electronic table of contents) service.

Whilst BL Direct ticks all the boxes in offering comprehensive access to online research articles through a single interface, it is hamstrung by the need to get universal acceptance from publishers to deliver electronic articles this way. Activity on BL Direct is also not as high as hoped for because of the costs of buying an article through the service.

Nevertheless, the existence of a recognised intermediary such as British Library Document Supply which can join up "islands" of content whether it be across publishers, digital and/or print etc, could be useful to end users. The BL search, order & delivery platform (Integrated Request Management Delivery System - launched September 2011) provides just that. It included the integration of meta data from publisher sites within the BL catalogues thereby providing a "shop window" for publishers' online material.

The BL analysed its customer segments and established the need for a set of tailored services to suit different market segments. Pharmaceutical R&D companies want speed and quality, whereas higher education institutes want low prices and quality. BL will seek more direct agreements that permit the use of e-born material (and store on BL servers or reach out to publisher web sites). The USP (unique service provision) will be the range of content, given that the BL has the advantage of holding much of the long tail (in print).

At present the combination of costs to the end user (publisher's royalty plus BL's operational costs) makes the intermediary uncompetitive as compared with buying articles directly from publishers (which charge just the royalty rate). Nevertheless, an indication of the range of users for the BL Direct service have been provided by the British Library and are shown below. The numbers are the requests made to BLDSC's BL Direct service in 2010.

Table 5.7. Spread of Demand for BL Direct supplied documents

Sector	***Number of Documents***	***Key sub sectors***
'Affiliated' (ie, attached to academia/large corporations)		
Student (undergraduates)	3,946	
Students (postgraduates)	4,577	Educ = 849; Arts = 430
Lecturers/Professors	882	Educ = 580; Arts = 88
Scientists/Lab Technicians	384	Chemists = 57; Med/pharm = 105
Librarian/Informat Scientists	584	
Archivist/Historian	154	
'Nonaffiliated' (not part of large research organisation)		
Nonaffiliated (Professional)		
Health Professionals	1,554	
Pharmacists	44	
Engineers	490	Equip eng = 161; Oil = 33
Computer Professionals	121	
Legal professionals	236	
Designers	158	
Journalists	105	
Editors	102	Medicine = 29; Educat = 18
Teachers/Trainers	456	
Nonaffiliated (Business)		
Senior executives	280	
Managers	746	Medicine = 79; Educat = 60
Consultants/Brokers	318	Environ = 58; Chemistry = 20
Financial	178	Accountant = 55; Banks = 49
Sole Traders (SMEs)	135	
Human Resources	102	
Marketing/PR/Sales	294	
Patent/Trademark agents	25	
Buyers	69	
Translators	26	
Nonaffiliated (Individuals)		
Authors	232	
Inventors	31	
Personal Researchers	776	
Picture Researchers	10	

Professional Researchers	1,230
PA/Secretaries/Clerical	326
Retired	424
Unemployed	101

Source: Personal communication with BL staff. Based on internal documents relating to 2010 activity.

The dominant areas are the academic sector (10,500 requests), followed by 3,300 in the professions, 2,200 in business and 3,100 individuals.

There is therefore not much evidence of the Long Tail of document demand from the above figures. The ‘affiliated’ (academic) group representing the core of the Long Tail exceeds the ‘unaffiliated’ (knowledge workers outside academia) by 10,500 to 8,600. BL outreach is still largely academic focused.

5.9. ENVIRONMENTAL AGENTS FOR CHANGE (A)

The consensus among observers of the STEM scene is that the industry is at the cusp of a change in the paradigm. All stakeholders in STEM, notably publishers and librarians, will need to adapt to the changes which are taking place.

This next section identifies factors which are expected to have influence on the way researchers in all institutions may be affected by changes which are taking place in society. This chapter (5.9) focuses on the various sociological and technical changes which impact of researchers including UKWs; a later chapter (6.4) looks at the publishing developments, policy issues and changes in the science and how these relate to STEM and its alleged dysfunctionality.

Though STEM and UKW and their changes are treated in separate chapters, there is connectivity between the two.

Methodology

The methodological approach is based on describing the research process – one that provides the ‘world view’ affecting the STEM information industry and its users including UKWs (Pickard, 2013). This world view comes from an analysis of views of acknowledged industry experts to see whether there is consensus to which each of them subscribe regarding future scenarios for scholarly communication. These experts have written about their expectations for change, in many instances in monographs. From an analysis of these works a number of driving forces which will force change in STEM have been identified. In addition, several models have been developed which show how these changes will affect the overall environment within which STEM will be active in the next five to ten years.

These models incorporate external and internal developments affecting STEM. Each of the developments are, where appropriate, cross referenced to the main body of the text. They constitute the building blocks on which this particular research into the STEM and UKW developments has been based.

A contextual, long-term view which such a model/concepts approach offers is missing from most research studies made of the STEM industry thus far, and yet such a strategic approach offers a better indication of the extent of the challenges which the STEM industry faces, and how it will need to adapt to the inclusion of UKWs. As such this next chapter offers a novel approach to understanding the issues facing both STEM and UKWs.

5.9.1. Chaos Theory

Even with the aid of the research paradigm of world events and conceptual paradigm modelling, determining the direction which STEM and the knowledge worker sectors will take is not easy. Forecasting the future is difficult under any circumstance. It is suggested that aspects of chaos theory can be applied to the current situation. There are many variables which have influence on trends in the scientific domain and these are often sporadic rather than continuous in their effect. Some have high relevance in promoting a changed paradigm, whereas others may appear to have marginal effect and therefore be understated. The analogy frequently used is the 'Butterfly Effect' – a butterfly beats its wings in the Amazon and this will influence weather conditions on the other side of the world. Such is the volatility and extent of variables involved in an unstable business environment.

Though chaos theory has its roots in mathematics its applicability spreads beyond to the information industry and can be used as an analytical assessment of STEM's future. The point is that many and diverse dynamic systems interfering with research and science creates difficulty in enabling long-term accurate predictions of the future industry structure. There is no one single determinant, no linear extension of the effects of one variable which will lead to an accurate assessment of change.

At best the situation can be addressed through a Delphic model of scenario building, using the talents, expertise and knowledge of eminent authorities in the various sectors of STEM. There has been little evidence of this happening at a high level within the industry, though the European Commission has attempted to set guidelines in support of the European information economy (such as through the current Horizon 2020 and Innovation Union – see ec.europa.eu>policies>science_technology). There are no other significant examples of such a long view being given to the challenges affecting STEM and the inclusion or otherwise of UKWS.

The following section describes the building blocks for concepts and models which can explain the mechanics of the changes which could take place in the UKW space. These are:

Social Changes:
- Neurological adaptations
- Natural Group Size (the Dunbar number)
- Cognitive Surpluses

Research Procedures
- Sharing results of research
- Collaboratories
- Designed serendipity

Technological Trends
- Technology advances
- The Internet and the web
- Mobile devices (including smartphones)
- Valley of Death

In addition, there are similar background changes taking place affecting the STEM industry which will be described in chapter 6.

5.9.2. Social Changes

5.9.2.1. Neurological studies

Neuroplasticity, which describes how synapses within the brain adapt to changing stimuli, is the internal mechanism which enables individuals cope with social and technological challenges. This also includes their ability to absorb published research outputs.

Scientists have confirmed the existence of discrete nerve cells within the brain. These are neurons. They have central cores (or somas) and carry out functions common to all cells. However, they also have two kinds of tentacle appendages

– axons and dendrites – which transmit and receive electric impulses. When a neuron is active, a pulse flows from the soma to the tip of axon, where it triggers the release of chemicals called neurotransmitters. The neurotransmitters flow across synapse and attach themselves to a dendrite of a neighbouring neuron. This triggers or suppresses an electric pulse in that cell. It is through the flow of neurotransmitters across synapses that neurons communicate with one another. Thoughts, memories, emotions – all emerge from the electrochemical interactions of neurons, mediated by synapses.

With the above as background, it is evident that the brain is constantly changing – unlike traditional assumptions, it is not a static entity that is subject to longterm decay. It is highly plastic and can change as circumstances dictate. The plasticity of the brain, or its adaptation according to changed circumstances affecting the individual, is an important factor in dictating how researchers are adapting to the technologically-driven new communication media.

There has been much recent research into changes in researcher behaviour as people adapt to the new informatics environment. Research is focused at an individual neurological level, but the implications from aggregating the results to special groups and the whole community is profound. One popular report published by the team headed by Professor Eleanor Maguire, a cognitive neuroscientist at UCL, showed that the brains of London's taxi drivers' change and grow as they develop their knowledge of the city's streets. The part of the brain dealing with navigation - the posterior hippocampus – is larger among the test case of 16 taxi drivers compared with other individuals (Maguire et al, 2000). More disturbing is that as taxi drivers improve the size of their posterior hippocampus it is at the expense of the adjacent anterior hippocampus, which lowers their ability to cope with other special processing tasks. It suggests the brain is like a muscle, and as a muscle it can expand and be enhanced by constant use and exercise, often at the expense of other brain functions. Taxi drivers constantly use the navigational part of the brain to optimise taking passengers to their chosen destinations.

In "Mind Change", Baroness Greenfield (Oxford University) claims technologies are creating a new environment and our minds are physically adapting: they are being 'rewired' (Greenfield, 2005; 2015). Though her conclusions of a rewired brain particularly as it affects children are not universally accepted – critics point to her reliance on anecdotal data and not extensive evidence-based results – her opinions have nevertheless sparked debate.

One view proposed by Greenfield is that reading habits are being affected, and that short items are preferred over longer ones. A switch to skimming and away from in-depth reading has unfortunate consequences. Greenfield claims that by ingesting only small bits and bytes of information – rather than getting involved in detailed linear reading – the Netgeners (the Internet Generation) will fail to develop intellectual skills necessary for higher order thinking. They may develop a digital version of ADD – attention deficit disorder – zigzagging between ideas without contemplative finishing anything (Greenfield, 2005).

A further instance of the problems created by the rise of easily-accessible digital information is that it is creating an overload in a researcher's working memory, which in turn affects the ability to assimilate new information into the larger longterm memory. Cognitive overload of shortterm memory is created not only from increased information available on the Net but also compounded by the many hypertext links being introduced into online text, and more recently by additional links to multimedia content. Unlike with education, where such resources can be harnessed and directed at improving the educative process, with STEM research information it introduces too many distractions. Such distractions have been shown by many research studies to have reduced the effectiveness of the research process. There is a dichotomy. On the one hand the Net empowers the researcher with the ability to keep up to date – on the other it creates many distractions which run counter to a deliberative and focused research analysis. This is a dichotomy facing Google for example – on the one hand it aims to be the world's online library. But in doing so is in the business of facilitating distraction. It acts against contemplative reading in favour of generating frequent clicks which in turn feeds into a lucrative AdWord advertising algorithm.

Other pundits also challenge the benefits from new forms of technology in information and online communication. Carr (Carr, 2008) wrote in an article in *Atlantic Magazine* (July/August 2008) and again in his book "The Shallows" (Carr, 2010) on how Google was making the world stupid. His argument was also that the snippets of information which the information explosion has created, and being made available through Google, was again at the expense of in-depth reading of books and articles. There was no longer any 'quiet space' into which end users could retreat. He claimed “A new intellectual ethic is taking hold. The pathways in our brain are [again] being rerouted”.

Carr suggests that the synapses in the brain require reinforcement to remain ‘live’ (Carr, 2008; 2010). He no longer reads articles or books as he and his colleagues find it increasingly difficult to concentrate on lengthy text. One set of synapses are in decline (in-depth reading); another set are being reinforced (browsing and skimming). Other researchers have shown that the process of online searching effects changes within the dorsolateral prefrontal cortex, changes which are not apparent in those who rely on printed literature for their knowledge input (Small, 2008). The result is that the mode of communication will change as our reading patterns change. It could be that lengthy descriptions in scientific reports are passé as far as being the main vehicle for future scientific communication, and snippets/abstracts, synopses or, more likely, granularised parts of a report or dataset, become more important. In a terse overview, Carr claims that the traditional mind is “As supple as it is subtle”. He also reflects on their being “the imaginative mind of the Renaissance, the rational mind of the Enlightenment, the Inventive mind of the Industrial Revolution, even the subversive mind of Modernism. It may soon be yesterday’s mind”.

Eric Schmidt, chairman of Google, became almost apologetic about his institutional affiliation when he reported “I worry that the level of interrupt, the sort of overwhelming rapidity of information …. is in fact affecting cognition. It is affecting deeper thinking. I still believe that sitting down and reading a book is the best way to really learn something, and I worry that we’re losing that” (Scohnfeld E. 2009).

Though these significant if controversial views are not universally accepted, it does imply that traditional information habits may be modified as a result of external developments affecting individual’s neurological processes. More specifically, it has implications on how information should be formatted to cope with the needs and habits of a wider knowledge worker audience which does not, and has not, relied on lengthy, specialised textual treatises for their information.

These differences between the traditional and emergent researchers also find their roots in the structure of the social group.

5.9.2.2. Natural Group Size

Looking at groups rather than individuals, Dunbar, a Oxford University anthropologist, has suggested that the ‘natural size of the group’ is about 150 individuals (Dunbar, 1992). That is the number of people with whom most humans can maintain a stable relationship. These are relationships in which an individual knows who each person is in their contact network, and how each person relates to every other person.

Dunbar theorised that “this limit is a direct function of relative neocortex size, and that this in turn limits group size ... the limit imposed by neocortical processing capacity is simply on the number of individuals with whom a stable inter-personal relationship can be maintained” (Dunbar, 1992). The Dunbar number is about the same as the number of people in a typical pre-industrial village, a professional army unit, the Roman army’s centurians, a Hutterite farming community, and, more relevantly, a scientific sub-speciality.

However, social networks, and services such as *FaceBook*, have created a new form of social bonding which replaces the traditional idea of the natural group size. *FaceBook*, *LinkedIn, WhatsApp*, etc., enable many thousands of people to group together in a communication network without creating tensions of pressures on the system or the people involved. The NetGeners use communication processes such as *Twitter* which are orders of magnitude larger, far more sophisticated and much more efficient than the networks which were possible for older generations served by printed books, journals and written letters.

This extension beyond the Dunbar figure, leading to hundreds or thousands of people being part of any one researcher’s social network, enables researchers outside the traditional world of a closed knit academic audience to be reached. Unaffiliated Knowledge Workers can therefore more easily be brought within the developing capacities of the technology-enhanced neocortex.

5.9.2.3. Cognitive surplus

Resulting from improvements in productivity over centuries, an increasing amount of personal time is now available to perform non-work related activities (Shirky, 2010). This is the basis from which greater participation in network science, collective intelligence and the use of social media can take place. The time and spaces from work which did not exist in the 20th century are now being filled by the experience of not just being a consumer (of broadcast material) but also becoming an active participant and producer.

It is claimed that TV watching in the UK involves over one trillion hours of 'free time' being spent (Ofcom, 2014). If only 1% of this were to migrate to a science-based sharing and collaborative platform this would mean a radical change in the structure of the information/entertainment industry. This is the latency which exists in society and can be tapped into, providing the right motivations to participate in STEM can be found.

5.9.3. Research Procedures

Social media supporting social networking is now firmly entrenched as part of society's communication infrastructure (*Facebook, Twitter, Youtube*, etc). Researchers are now also waking up to the advantages social media offers for their research activity, and are translating some of the new media features into science communication to improve their research experiences.

The transition from a singleton-focused research process to global collaborative Big Science projects and beyond is not linear. It occurs in a number of stages. The starting point is the research process with a strong scientific ethic dictated by the need to ensure quality of the scientific record. During the 1990's, office standardisation processes were being adopted by researchers. These included back-office services such as email, project management procedures, standard forms for fund applications, protocols, etc. During the early years of the current millennium new technology tools became available, which together with social media have led to a further stage in the research transition - that of systematised research. It involves applying sophisticated technology to replace what was traditionally a manual operation. Robotics in surgery and dentistry; CAD in architecture are instances of the new approach in the research transition. A further stage is the externalisation of the research effort. This involves digital dissemination processes to create and access a wider range of research outputs. The next stage is still in embryo, but with the spate of technology and social developments currently underway, the paradigm for research is likely to change again in the foreseeable future (see Susskind, 2015).

Arguments against a smooth transition occurring from where research was in the 1980/90's and now referred to as the Hype of the Product Life Cycle (see 6.4.1.5) where the flow from product inception to universal adoption goes through a number of phases. It is an uneven flow. Adoption of new research practices could fail (or succeed) at any stage in the cycle.

5.9.3.1. Sharing results

Underpinning the above multi-staged developments and social media adoption is the assumption that researchers are prepared to share information and experiences with others without equivocation, particularly with and among UKWs.

This is a critical aspect of future behavioural patterns - the willingness to 'share' at all stages in the research process. In Shirky's "Cognitive Surplus" book (Shirky, 2010) he comments on studies, many built around Game Theory, suggesting that there is inbuilt within society the willingness to collaborate and share rather than be selfish. This has been supported – from a neurological point of view – by Lieberman in his book "Social – why our brains are wired to connect" (Lieberman, 2013). An improved sharing of common resources is accomplished when all participants act without compulsion. There is a social mechanism which is behind this - it is not destructive or aggressive but one which treats individuals as non-exploitable items.

This support for sharing leads to participation in the communication process by a far wider group than has hitherto been the case. It enables knowledge workers to share their thoughts and experiences with hardcore academic/researchers on the basis of collegiate and a level playing field.

However, sharing information is not always as ingrained into the individual scientist's psyche as participation in some large collaborative projects might suggest (see Citizen Scientists chapter, 5.6 above). Most career minded scientists have traditionally had little incentive to contribute to open-sharing sites and instead the focus was on doing what has been done over decades – to ‘publish or perish’. To create articles which are published and cited and give international recognition for the research efforts of the scientist concerned. “Their data is the raw record of experimental observations and may lead to important new discoveries” (Neilsen, 2011). It is the special edge which a researcher’s quality publications would give them over their peer group with whom they compete for funding, promotion and international recognition.

The fear is that openly shared sites create opportunities for stealing results before they become attributable to the original author, or even allowing false and bad results to be disseminated. The history of scientific development is strewn with examples of scientists stealing data from others, plagiarising other works. It is the black side of science and scientific publishing.

Another barrier to sharing comes from research which leads to patents applications or developing a commercial product. This is where basic research, traditionally undertaken within universities, comes up against the proprietary aspects of applied research, undertaken in industry but also increasingly within universities under contract. It needs a change in behaviour and administrative procedures within corporations and research institutes if sharing is to succeed across those disciplines which have an industrial application.

This protection of the individual’s research activity conflicts with neurological trends which research into social networking is exposing. Neurologists point to the importance of dopamine as a stimulant for enjoyment within the brain. Small releases of dopamine occur whenever an individual participates in a social networking site such as *FaceBook*. According to Greenfield (Greenfield, 2015. p110) “Going on *FaceBook* is physically and/or physiologically exciting”. Dopamine has the same effect on gambling, arousal, reward seeking and addiction – blips of dopamine which occur when experiencing interaction on social networks become not only rewarding but also, allegedly, compulsive (Greenfield, 2015). Harvard researchers have demonstrated that sharing personal information activates the reward systems in the brain the same way as food and sex (Tamir et al, 2012).

It leads to the social mind accepting loss of some aspects of privacy – no longer holding back on making personal information available - in favour of sharing. According to Mark Zuckerberg "People have really gotten comfortable not only sharing more information and different kinds, but more openly and with more people and that social norm is just something that has evolved over time" (McCullagh, 2010). Again from Zuckerberg "There is a huge opportunity to get everyone in the world connected, to give everyone a voice and to help transform society for the future…… As people share more they have access to more opinions from the people they trust about the products and services they use. This makes it easier to discover the best products and improve the quality and efficiency of their lives". Sharing now reaches an average of 262 people for each of the one billion *FaceBook* users and over 510 'friends' as far as the average youth is concerned (Arbitron, 2013).

There appears to be a psychological disposition for self-disclosure brought to fruition in a social networked world which trumps traditional adherence to personal privacy. "If identity is now constructed externally and is a far more fragile product of the continuous interaction with 'friends', it has been uncoupled from the traditional notion of, and need for, privacy" (Greenfield, 2015). With a reduced commitment to privacy the gates are opened to support greater sharing in a social networked environment.

This issue was referred to in the chapter on Citizen Science, where sharing and the 'hive mind' has become a significant aspect in the emerging research activity (see chapter 5.6). The point is made that sharing, cooperation and collaboration exert a powerful new influence on the emerging digital natives in a way unknown within researchers in a printed world.

5.9.3.2. Collaboratories

Much research involves teams of specialists acting in close cooperation. Not only within universities – significant public and private research projects are being undertaken across many institutional types both in the UK and globally. The dominance of the single researcher breaking new research ground is fading and being substituted by moves towards Big Science (Price de S, 1963). Their coordination is guided by an ‘invisible hand’ (Smith A, 1776) towards joint discovery and innovation.

A collaboratory, as defined by Wulf, is a “centre without walls”, in which the nation’s researchers can perform their research without regard for physical location, interacting with colleagues, accessing instrumentation, sharing data and computational resources, [and] accessing information in digital libraries (Wulf, 1989). In essence, a collaboratory is an environment where participants make use of computing and communication technologies to access shared instruments and data, as well as to communicate with others. Neilsen describes several collaborative projects which harnessed the micro-expertises of individuals with different skills who would not normally come together (Neilsen, 2011).

This has led to networks of collaborators which can include academics, professionals and the general public, with a demand for effective real-time and fast communication support services.

Existing collaboratories include the Biological Sciences Collaboratory; Collaboratory for Adaptation to Climate Change; Marine Biological Laboratory; Molecular Interactive Collaboratory Environment (MICE); and the Collaboratory for Microscopic Digital Anatomy (source: definition of Collaboratory in Wikipedia). From 1992 to 2000 financial budgets for scientific research and development of collaboratories in the Unites States ranged from US$ 447,000 to US$ 10,890,000 and the total use ranged from 17 to 215 users per collaboratory (Sonnenwald, 2003).

Such collaboration was originally defined by Udell as ‘Designed Serendipity’ and adapted by Neilsen in his book “Reinventing Discovery: The New Era of Networked Science” (Neilsen, 2011).

5.9.3.3. Designed serendipity

Designed serendipity is the process whereby intractable technical problems facing a scientist are unlocked by finding the right expert at the right time to give the right answer. That person can be anywhere in the world. They can be outside the normal pattern of relationships found in the conventional research process. In the past such identification was difficult – with social media it has become easier.

Collaboration is key to designed serendipity. It is claimed that when we try to resolve a problem on one's own, most of the ideas can lead to dead ends. But when many people address the problem interaction increases through the 'network and multiplier effects'. It happens when the number and diversity of participants increases. The more this happens the greater the chances are of finding a way through the problem. The problem solving goes 'critical' and 'viral'. "Once the system goes critical the collaborative process is self-sustaining. That jump qualitatively changes how we solve problems, taking us to a new and higher level" (Neilsen, 2011). This issue was explored in chapter 5.5.4 where the role of agencies such as Innocentive as collaborative research platforms were described.

For those involved in designed serendipity it helps to focus on specific issues where a researcher has a special insight and advantage. In the digital world circulation of personal profiles online describing levels of expertise assists in matching skills with need on a collaboratory project.

Increasing the granularity of action points within the research topic also improves prospects for more individuals with different expertises to become involved – expertises which may not necessarily be available within the academic world. UKWs bring practical and applied knowledge and give new insights on how pure research problems can be resolved within budget and time constraints.

There are some essential aspects to designed serendipity. In essence:

- In society there is a tremendous amount and range of expertises
- This expertise can be small elements of an overall problem to be solved
- The expertise is often latent
- Social tools enable such latent micro-expertises to be identified, activated and harnessed
- These online tools create an 'architecture of attention'
- Collectively this harnessing exceeds expertise of any one individual
- A series of such modular approaches may be necessary for large social projects to be managed successfully

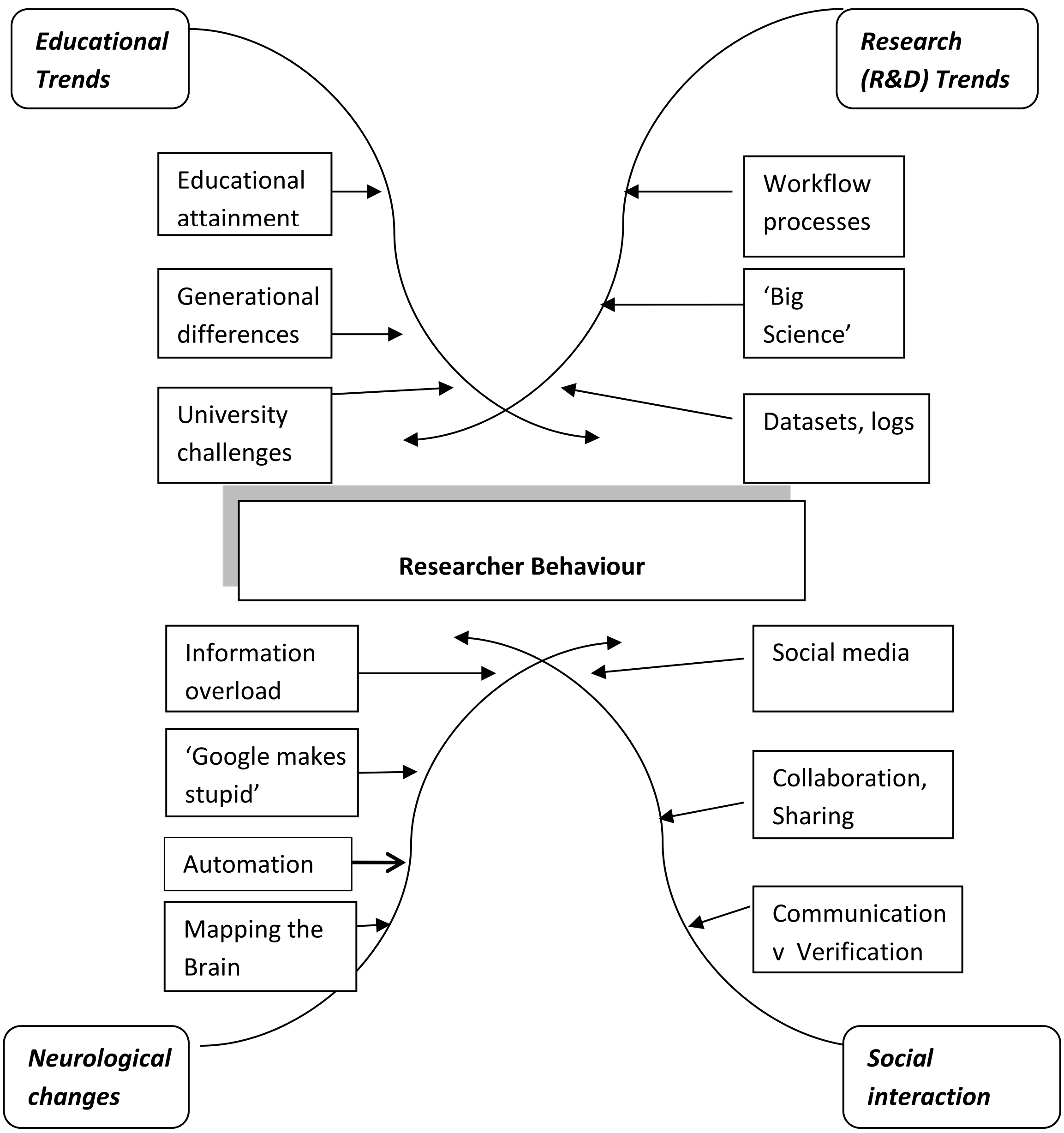
As a work flow process it builds on the individual-focused nature of the earlier research scientists, and through sharing, using online tools and collaboration produces a more effective collective intelligence. It adds another dimension to the democratisation of the research process, and enables the wider market of knowledge workers – with their individual often unique or esoteric skills and expertises – to be embraced within the scientific research process. In these instances, the larger the collaboration the better.

Participants in social groups do not necessarily agree with current copyright rules, but instead adopt their own version of what is acceptable – and that excludes profiteering from other's socially-created work. They do not want to inhabit a world of commerce but rather seek affirmation and recognition from peers. "Within the community purity of motivation inside the community matters more than legality of action outside it. Intrinsic motivations take precedence over extrinsic motives" (Shirky, 2010).

This suggests that an open, democratic information society is able to embrace the different needs of a new audience hitherto locked out of the old system. It brings in social groups which are found in 'the long tail' of the information industry – the unaffiliated knowledge workers.

The following chart brings together a number of sociological trends all of which will impact on the Researcher and change the way they operate.

Model 5.2. Sociological Trends



5.9.4. *Technological Trends*

5.9.4.1. Technological advances

The end of the twentieth century saw innovation in communications being introduced every bit as significant as the change which occurred with the introduction of moveable type by Gutenberg in the fifteenth century, and the subsequent launch of scientific journals in the mid seventeenth century.

- Underlying the spread of electronic information is Moore's Law (Moore, 1965). Moore, former chairman of Intel, pointed out that every eighteen months the number of transistor circuits etched onto a computer chip doubled. This 'law' has existed for the past 50 years – a tenfold increase in memory and processing power every five years. As an example, the cost of a single transistor in 1961 was approximately $10. By 1968 the transistor cost had fallen to $1. In 2009, Intel's processor chips had about two million transistors, which gives a per transistor cost of 0.000015 cents. The uniqueness of the microchip – essentially just sand – is in how cleverly it is put together. As a technological driver it is behind the current fall in prices of personal computers and the increased availability of devices such as smartphones, laptops and tablets to a wider community which includes UKWs. In future the role of developments in quantum computing will have additional impact on the efficiency of hardware technology.
- At the same time as Moore's Law was making its impact on hardware there were similar rapid technical improvements taking place in telecommunications. The total bandwidth of the communications industry, driven by developments in data compression made possible through fiber optic strands through which information can pass, is tripling every year. This effect is referred to as "Gilder's Law" (Gilder, 1993).
- A further related 'law' is 'Metcalfe's'. Metcalfe, developer of Ethernet, observed that the value of the network that is created by the above is

> proportional to the square of the number of people using it. The value to one individual of a telephone depends on the number of friends, relatives and business acquaintances that also have phones – double the number of friends and the value to each participant is doubled and the total value of the network is multiplied fourfold.

The triple effect of faster, better, cheaper technologies – affecting processing, storage and bandwidth – come together online which is why there are so many free information services available, from *Google, YouTube, Flickr, FaceBook*, etc. The services can be free because their operating costs are negligible spread over a global market of end users, funded by sponsors and advertisers, and brought to market at minimal cost using digital technology.

Though physical content or publishing output is influenced by other (editorial and commercial) forces, technological advances provide the means whereby content - books, journals, articles, data and supporting multimedia - can flow quickly and efficiently through the research system. But in addition they create a technological infrastructure for information which supports a changed environment within which both knowledge workers and academic researchers could operate and collaborate.

Some computer scientists believe that new ‘neuromorphic’ microchips which have machine-learning protocols hard-wired into their circuitry, will boost computers’ learning ability in coming years,. Taking this a step further, if computers are advancing so rapidly, and if the natural state of people is to be slow, clumsy and error prone why not take the human factor out of the equation altogether and build self-contained systems. “We need to let robots take over” declared Kevin Kelly in a 2013 *Wired* article (Kelly, 2013) which in his view would improve efficiency, eliminate errors and reduce costs/prices. This returns to the concept espoused by McLuhan (McLuhan, 1964) in his book “Understanding Media” in which he foresaw the significance of the media itself in dictating the impact of the information revolution. His enigmatic aphorism - “the medium is the message” - has become a popular saying supporting the idea that content matters less than the medium itself in influencing how we think and act.

These affect business models. According to Anderson in his book ‘Free’ (Anderson C, 2009b), “Never in the course of human history have primary inputs to an industrial economy fallen in price so fast and for so long". This is the engine behind the change in the information economy, and sets the scene for greater democratisation of STEM information and for cost reduction in the creation of STEM outputs.

There is also an ongoing refinement to powerful global search engines. Gateway services such as *Google Scholar, Medline, Yahoo, PubMed, Scirus* and *Web of Science* are important initiatives in raising awareness of relevant publications. Such platforms and services enable links to remote information sources to be made quicker and easier.

These technological advances are not gradual – they are incremental and escalating in speed of implementation. They come in two forms - there are technological changes which arise from improved automation, increasing the efficiency of current book/journal publishing and online processes. There are also technological advances which arise from innovation, also referred to as 'disruptive technologies', which create new paradigms different from the print-based services. The combination is changing both the operations and the future vision for STEM.

The STEM information scene which existed ten years ago is different from that which exists today and will be radically different again within the next five years driven by such technological-driven progress. Technology - both automation and innovation - provides new opportunities for existing and different mechanisms for conducting STEM research. However, there are a number of pundits (Carr, 2016) who claim that the focus on automation and its emphasis on technical efficiencies could lead to balanced cultural values being undermined. In effect, software development will be carried along on a wave which will change the work and leisure activities of society and diminish creativity as knowledge workers grapple with the increasing dominance of screen-based information services and their distractions.

Nevertheless in the short-term, greater availability of devices such as laptops, netbooks, eBook readers, smartphones, Google Glass and tablets has increased access paths for potential readers of digital information. UKWs now have access to broadband. Networks of users are being created with communication being both cheap and reliable. There is an established technical and information infrastructure in place, ready to support delivery of research output in whatever format. UKWs are beneficiaries of all these technological trends and bring them to the doorstep of the digital revolution in scientific research.

5.9.4.2. The Internet

The impact of the Internet on scientific communication in recent years cannot be over-stated. It has transformed the information seeking habits of researchers. According to Weinberger in his book ‘Too big to know’ (Weinberger, 2012) there are several aspects to the Internet which are important.

- The Internet connects many people. The worldwide population is estimated at over 7 billion, of which 2.3 billion are connected to the Internet (and over 1.44 billion are users of *FaceBook*). This is a huge reach into global society achieved within the past three decades using Internet protocols (or two decades in the case of the World Wide Web).
- This has spawned concepts such as ‘the wisdom of crowds’ (Surowiecki, 2004) which challenges the authority of the expert and highlights the importance of wider input from an audience with different specialist experiences (see 6.4.2.3). It has led, for example, to crowd-sourcing (Howe, 2006) and citizen science as important research trends.
- In the past, working as singleton in small teams on carefully defined research topics may have been appropriate and practical. In future it may be judged inefficient in comparison with the exposure of the research problem to many researchers from different backgrounds and experiences that in unison can lead to the right answers more quickly. The Internet facilitates cross-disciplinary, cross-institutional interaction. This has resulted in ‘collective intelligence’, a concept described by Neilsen in his book “Reinventing Discovery – the new era of Networked Science” (Neilsen, 2011).
- The Internet is cumulative. The Net retains everything posted to it and makes the historical record easily accessible. This has negative aspects, but also positive in that it is an open record or archive of all that has been said that is important, indifferent and/or innovative.
- The ‘cloud’ of linked computer power provides almost limitless storage of digital records. It is the basis for building on the past, for ‘standing on the

shoulder of giants', for establishing precedence even if it lacks the professionalism involved in permanent archiving and curation.

- The Internet is flexible. It allows for unprecedented back and forth communication through services such as *FaceBook, Twitter, FigShare, LinkedIn, ResearchGate*. Millions of people can participate, but equally small groups of tens or more can take part in a highly specialised and targeted dialogue through Internet.

According to Weinberger, "the complex, multiway interactions [that] the Net facilitates means that networks of experts can be smarter than the sum of their participants" (Weinberger, 2012). This opens up a new approach to research interaction and effectiveness whereby the dominant force is no longer the skills of a few experts but rather the interaction of a broadly-based crowd. The inclusion of as much expertise from as wide a group of researchers – including knowledge workers outside academia – is a significant value-add supported by the Internet.

Much of new social media is dependent upon the infrastructure provided by the Internet. According to data from InternetWorldStatistics.com on July 29th 2012, the following global penetration of Internet has been measured.

Table 5.8. World Internet Usage and Population Statistics (2011)

World Region	*Population*	*Internet Users*	*Penetration (% of population)*	*Growth 2000-2011*
North America	347,395,000	273,068,000	78.6%	+153%
Oceania and Austral	35,427,000	23,927,000	67.5%	+214%
Europe	816,426,000	500,724,000	61.3%	+376%
Latin America	597,283,000	235,820,000	39.5%	+1,205%
Asia	3,879,741,000	1,016,799,076	26.2%	+790%
Africa	1,037,524,000	139,875,000	13.5%	+2,988
Total	6,930,055,000	2,267,234,000	32.7%	+528%

Sources: Internet Usage and World Population statistics are for December 2011. Population numbers come from US Census Bureau. Internet usage data comes from International Telecommunications Union.

There is a cultural divide between those generations which grew up before the arrival of digital technology, from those who know no other world than one in which interactive digital technology is ubiquitous (see section 5.10). Each generation expects its own unique requirements for information to be met, in many respects these expectations are defined by attitudes or major events which took place in their formative years, but also the current and future availability of new communications technology. This is particularly true of the digital generation in which broadband, iPods, mobile phones, laptops and iPads became all-pervading and essential features of life, and determine much of the way people now communicate.

The key functions which can be addressed in this new digital communal mindset are 'connections' between information artefacts; 'links' between items; 'transparency' and 'openness'. These are part of the Internet culture. There are also virtues such as 'publicness', 'generosity' and 'listening' which build up trust in the communication system. There are also other ingredients such as efficiency and technical competency (Neilsen, 2011).

In business terms the emphasis is on 'market niches', 'platforms' and 'networks' rather than brands. Brands, which were the Holy Grail for journals, are no longer such valuable assets, but instead what has become important is establishing a relationship between producer and consumer. This relationship has been identified as 'prosumption' (Tapscott and Williams, 2006), an active collaboration between creators and users, and not just presenting something to a static unresponsive (or supply-driven) market. Speed and abundance of information also help to distinguish the Old (print based) from the New (digital based) information environments.

5.9.4.2.1. Web versus Apps

The Internet itself is also in transition. It was the transport vehicle for the World Wide Web, but recent years have seen the decline of the web in favour of semi-closed platforms and applications or Apps. The latter has been driven by the rise of the iPhone model at the expense of HTML which constrains Google-like crawling. "Dedicated platforms often just work better or fit better into their lives"

(Anderson C & Wolff, 2010 p 3). They are designed for single purpose and optimal mobile experience.

A similar dichotomy exists with online access. As a proportion of US Internet traffic, the Web had declined from a peak of about 50% in 2000 to 23% in 2010, and is still shrinking. The emphasis on specific platforms such as *FaceBook* and *iTunes* has emerged. Video (51%) and peer-to-peer communication (23%) had by 2010 taken dominant positions on the Internet. All of which indicates that use is increasingly made of the Internet, not specifically the Web.

This issue is highlighted graphically in the different technological positions adopted by two leaders in the information industry in recent decades - Steve Jobs and Bill Gates. Bill Gates adopted an open architecture for his Microsoft operating system which in a short period of time became an industry standard. Many computer manufacturers licensed the system and built it into their own products, in different ways for different purposes. The result was rapid adoption of Microsoft software but within a plethora of competing products, potentially confusing the end user in the process. The alternative model pursued rigorously by Apple was end to end integration to create a uniform end user experience - hardware, software, content and applications. This reduced the ability for innovation to be applied by third party organisations (Isaacson, 2011). Both models were successful. Both led to technical progress.

Though only a few of the evolving Internet-based services focus on scientific research, it raises the probability that traditional inequities in the scientific communication process, such as the fate of the disenfranchised knowledge workers (UKWs), could be overcome as further technical advances are implemented. Recent developments on the Internet support the idea that there will be more interaction, even among knowledge workers, as the so-called ‘generative Web’ takes hold where openness prevails. This makes the basic assumption, however, that the mindset of the research community is amenable to adopting new technical advances in communications – that they relate proactively with technical developments.

5.9.4.3. Mobile Devices (Smartphones)

There is evidence of a switch taking place from desktop to handheld devices (such as smartphones) as a means of information gathering. This trend places an onus on how STEM information should be formatted to meet this need (Nicholas, 2013a).

There are more than 6 billion mobile-phone subscriptions throughout the world. Of these about 2 billion are smart-phone users with connections to the Internet. This latter is estimated to double to 4 billion by 2020 (Economist, 2015).

According to CIBER Research Ltd the mobile revolution will result in further disintermediation within scientific communication. More people have phones than computers. With the change in screen size available on smartphones and tablets has come a change in the way information about research output is sought and delivered online.

Within STEM there is anecdotal evidence of use being made of smartphones for accessing STEM material, though it is more in the form of metadata/abstracts rather than full text articles. Approximately 10% of usage is from mobile devices, higher in areas such as clinical medicine (Ware, 2015).

In their 2015 Communications Market Report, OfCom found that smartphones have overtaken laptops as the most popular device for getting online (OfCom, 2015). Two thirds of the UK population now own a smartphone, using it for nearly two hours every day to browse the Internet, communicate, access social media, bank and shop online. Ofcom also found that a third (33%) of internet users see their smartphone as the most important device for going online, compared to 30% who still prefer their laptop. The rise in smartphone use marks a clear shift since 2014, when just 22% turned to their phone first, and 40% preferred their laptop.

Research undertaken by CIBER on the EU Europeana project involved an analysis of usage logs of this cultural, multimedia website which started tackling the mobile challenge in 2011 (Nicholas, 2013a; 2013b). The information behaviour of 150,000 Europeana mobile users was examined in 2012 and compared with that for desktop users. The main findings were that mobile users are the fastest-growing user community - a growth rate five times faster than that achieved by PC and desktop users.

Mobile telephony is generating a ‘time shift’ in behaviour. Visits are different from those using desktops. Mobile phone visits are information ‘lite’, typically shorter, less interactive, and with less content viewed per visit. Use takes on a social rather than office rhythm, with use peaking at nights and weekends. Many Europeana site visits occurred on Saturday nights for mobile users; for fixed devices such as PCs, it was Wednesday afternoon. The stimulus behind the growth of mobile telephony for scientific information and cultural purposes, according to the Europeana results, is that people trust their mobile and smartphones, and they are convenient and ubiquitous. It also indicates a coming together of entertainment and scholarship through the medium of the smartphone.

It appears “instead of information-seeking and reading taking place in the library and office, it will take place on the train, coffee shop, and around the kitchen table” (Nicholas, 2013a). The varied environment and context changes the nature of searching and reading, according to CIBER.

> “While the first transition, from the physical to digital, transformed the way we seek, read, trust, and consume information, until relatively recently the environment and conditions in which scholars conducted these activities had not really changed – it was still largely in the library or office, sometimes the home. However, with the second transition to the mobile environment, information behaviour is no longer mediated or conditioned by the office or library (and its rules and impositions), but by the street, coffee shop, home; in a nutshell by current social norms” (Nicholas, 2013a).

Mobiles are part of the digital consumer purchasing process — they are used to search for information prior to purchase, during the process itself, and to make the actual purchase (Nicholas, 2014b). It is possible that UKWs, who are also digital consumers, will be given scope for moving down an analogous pay-per-view route in accessing STEM information in future**.** There is also a pricing/charging mechanism which needs to be considered, one which is more linked to Apps than document delivery charges. In practice there is already a procedure for paying for services through mobile phones which could be used by UKWs for STEM purchases.

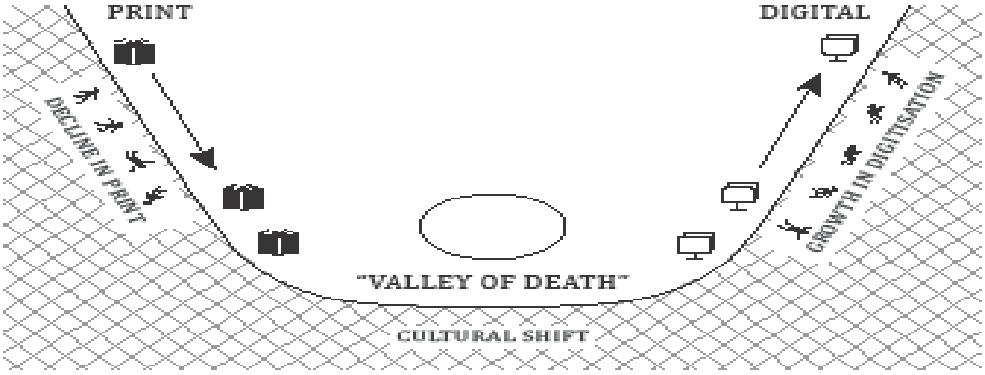
5.9.4.4. ‘Valley of Death’

Another feature of the STEM publishing system is organisational attitude towards new technology, and their adaptation to developing new STEM products/services. As indicated above, the traditional model for scientific publishing is based on print-based technology which goes back centuries. In future the introduction of more digital and networking technologies will be appropriate.

An analogy for this is that print-based publishing is on a downward slope of a valley. It is dictated by tradition and a print-based culture. On the other hand, the internet and digital publishing has created new ways of disseminating information online, and these processes are increasing, driven by the forces of the ‘perfect storm’. This can be reflected in the upward slope of the valley. The greater the rate of digitisation/networking the steeper the upward slope.

At the bottom of the valley is where the two cultures collide. The challenge facing publishers is to take the best and most durable parts from the print culture, from the downslope, and integrate it with the best of the upslope technologies in a way which gives publishers viable and long term survival, and researchers a valuable service. This is implicit in meeting the investors’ financial support for the industry – if the valley floor is not traversed in a logical and commercially sustainable way then their investment funds will be diverted elsewhere. The concept described is that of a ‘valley of death’.

Graph 5.3. ‘The Valley of Death’

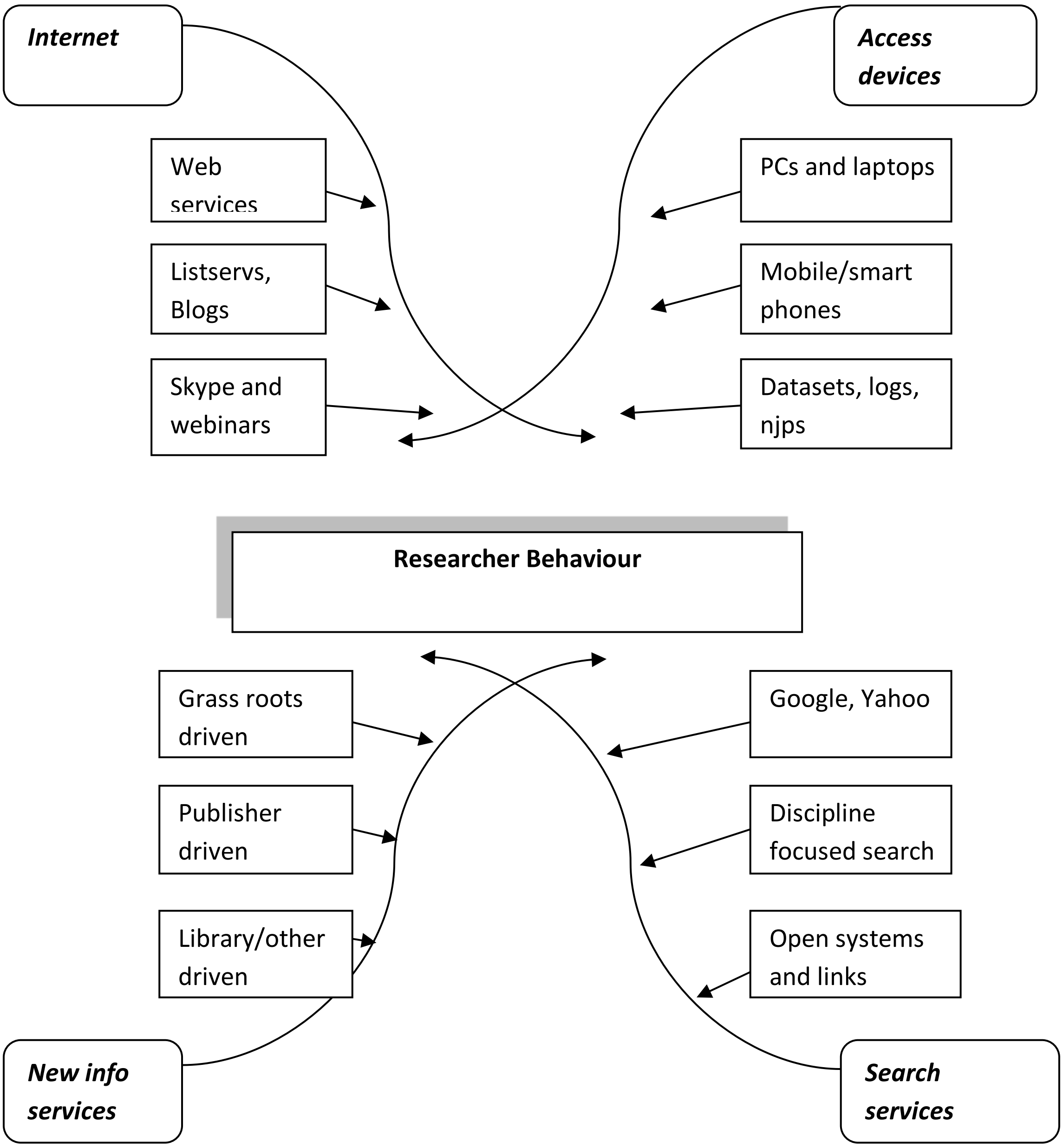


Source: Brown D, ‘Access to Scientific Research’, Berlin: de Gruyter, January 2016

This collision between print and digital without an effective transitional strategy means that UKWs are potential beneficiaries as old barriers to access are brought down and new more open digital opportunities are created.

The various technical trends can be brought together in the following graph.

Model 5.4. Technical Trends



Summary

It is no longer an option to view the creation and use of STEM information as an issue whose problems will unravel gradually and which will use established procedures for confronting external challenges. Both sociological and technical change are dynamic, volatile and significant in the digital world that it is altering the basis of the STEM industry. It is a tsunami rather than a gradual evolution.

The consequence is that the map of the user population for STEM in future needs to be redrawn. Opportunities arise for embracing a wider audience within STEM, and in so doing create new business models to enable a larger community to be reached. It has its effect on those involved. There is even a new term for participants in the business - they are no longer just ‘researchers’ but now ‘digital natives’ and ‘digital immigrants’ (Prensky, 2001).

5.10. DEMOGRAPHY

5.10.1. Demographic Trends

5.10.1.1. The Digital Scholar

Have these new informal communication channels made an impact on formal scientific communication? So far there is little evidence of a breakthrough. As Weller writes in his book “The Digital Scholar” (Weller, 2011):

> “These emerging themes [crowdsourcing, lite connections, online networks] sit less comfortably alongside existing practices and can be seen as a more radical shift in research practice. A combination of the two is undoubtedly the best way to proceed, but the danger exists of a schism developing between those who embrace the new approaches and those who reject them, with a resultant entrenchment to extremes on both sides [see ‘Valley of Death’ in section 5.9.4.4]. This can be avoided in part by the acknowledgement and reward of a new form of scholarship.” (Weller, 2011)

The schism is a reflection of different patterns of behaviour between a researcher as a digital immigrant and digital native. This was made evident during the interviews conducted by phone for this thesis among UK researchers (see Methodology and Case Studies reported in the Appendix 3). The ‘dinosaur’ sector, which focuses on formal publications and personal contacts as the prime source for scientific updates, accounted for half the respondents (digital immigrants), compared with the other half who were self-confessed ‘grubbers’ among all that social media had to offer (digital natives).

Schonfeld made the point that academics have been groomed by the Internet experience. "Academics expectations for user experience are not set by reference to improvements relative to the past, but increasingly in comparison with their experiences on consumer Internet services and mobile devices" (Shonfeld, 2015).

Science communication is slowly adapting to these changes, and also to a world where *Google* dominates the search space, and *Amazon* makes online purchasing easy; where *eBay* and *Paypal* set the parameters for selling and buying individual items; where *Skype* and *Viber* make connections and communications cheap and easy; where *Facebook, Twitter* and *LinkedIn* open awareness of personal and professional activities. With the new paradigms being explored as society moves towards openness, and as technology platforms are being created to satisfy emerging social trends for rapid communication, there is an opportunity to re-write the scientific communication manual and not be constrained by past practices and the survival needs of current stakeholders.

5.10.1.2. The Net Generation

There is the rise within society of the so-called 'Net Geners' (born since the emergence of the Internet) or 'X' generation. Their reliance on informal, digital information sources challenges traditional reliance on formal printed books and journals as the primary means of scientific communication.

The following table summarises the main generational classifications currently in use:

Table 5.9. 'The Generations' – a UK overview

Social sector	Proportion of total (source: Ofcom)	Born within years	Related definitions
Pre Boomers	18%	Up to 1946	
Boomer Generation	24%	1946-1964	Baby boom generation
Generation X	16%	1965-1976	Baby bust generation
Net Generation	28%	1977-1997	Milleniums or Generation Y
Next Generation	14%	1998- present	Generation Z

These 'generations' reflect a gradual transition from print-age into digital, with the younger generations seeing the digital options as being more attractive than earlier information systems. Such generational typology exists as much in the unaffiliated sectors of knowledge workers as within the affiliated. Support for this generational divide comes from anecdotes included in published works by Greenfield, Carr, Tapscott and many others (Greenfield, 2015; Carr, 2010; Tapscott, 2008).

Marc Prensky, an American technologist, coined the term 'Digital Native' for someone defined by their perceived outlook and abilities, based on a familiarity with digital technologies. By contrast 'Digital Immigrants' are those who have adopted aspects of new technology but still have one foot in the past (Prensky, 2001). Digital Natives know no other existence than through the culture created by the Internet, laptops and mobiles. "They can be freed from the constraints of local mores and hierarchical authority and, as autonomous citizens of the world, they will personalize screen-based activities and services while collaborating with, and contributing to, global social networks and information services" (Greenfield, 2015 pp4-5).

Another advocate for the change in the way digital natives create and disseminate information is Tapscott. Tapscott's books – "Growing up Digital" (Tapscott, 1998) and "Grown up Digital" (Tapscott, 2008) – rely on evidence collected from the new generation (Net Geners) of information users. 'Net

Geners' are defined as a social group with attributes different from Baby Boomers. He claims NetGeners exhibit a powerful social conscience. They are more participative within society, more collaborative, and supportive of greater openness than earlier generations. They make considerable use of Internet communication tools now available to them. Net Geners have different mindsets and skills, created to some extent through early exposure to IT, interactive gaming, and the Internet. These skills are just as relevant as the old linear skills learnt by the Baby Boomer generation, but are more appropriate in taking advantage of the opportunities which informatics, the Internet and digital communication systems offer.

In pre-digital times, during the Boomer and generation X periods, the focus was on collecting 'eyeballs', on establishing site stickiness, but overall it was using static presentation platforms to broadcast to audiences. The big change came with XML which allowed collaboration and interactivity in creating communities with like interests. "The old Web is something you surfed for content. The new Web is a communications medium that enables people to create their own content…." (Tapscott, 2008). The Net generation is in many ways the antithesis of the TV generation. This shift from one-way broadcast media to interactive media is profound. The distinction between bottom-up and top-down organisational structure is also at the heart of the new generation, with the Net Geners relating more closely to a more democratic bottom-up approach.

Tapscott explored eight characteristics which differentiate the Net Generation from the earlier Baby Boomers. These include:

- Freedom is prized
- Customisation and personalisation of things for their own specific needs becomes important
- Collaboration, not Diktats from above, to produce new extended relationships
- Traditional organisational structures and procedures are scrutinised more intensely
- Integrity and openness is demanded, as is transparency
- They want to have fun, be entertained and play
- Speed is a prerequisite
- Innovation becomes an essential feature of life

They influence each other through so-called N-fluence Networks – online networks of Net Geners who, among other things, discuss brands, companies, products and services. They do this by creating online content. This can be in the form of blogs, wikis, bulletin boards or other online combinations. Some 40% of US teens and young adults have their own blogs, according to US Pew Research Center (Duggan, 2013a; 2013b). In this way "they are democratising the creation of content, and this new paradigm of communication will have a revolutionary impact on everything it touches…" It suggests that the writing is on the wall for broadcasting services – TV as well as newspapers, and possibly parts of the scientific communication process.

As Shirky pointed out in his book "Here comes Everybody" (Shirky, 2008), two decades ago supply of published information created its own demand. Now demand is creating its own supply which means user needs is driving the creation of product. Users are making their own results available online. Scarcity is no longer an issue in an era of massive digitisation, data compilation, and tumbling costs of technology.

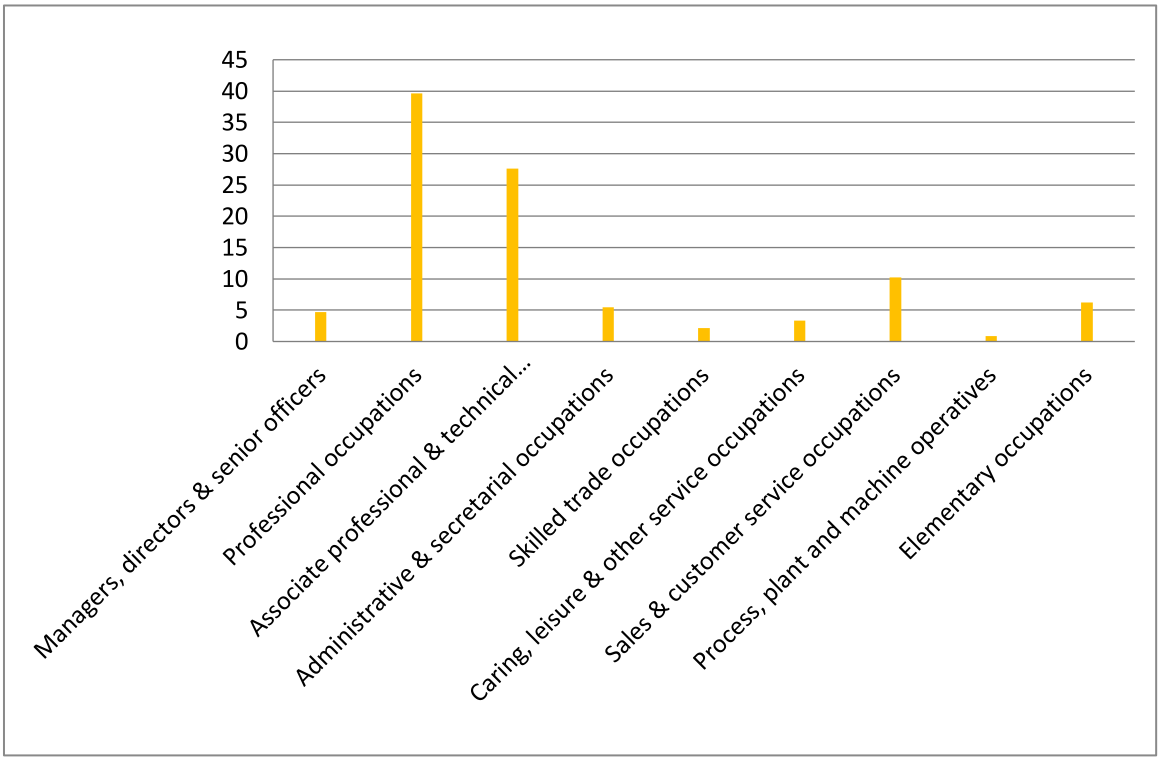
It also suggests a new working relationship with social institutions. Net Geners take active part in creating new products and services which match their customised and personalised needs. This activity was first identified by Toffler when he referred to the 'prosumer' (Toffler, 1970). Tapscott extends this to 'prosumption' – the interaction of consumption with production to influence the creation of useful products and services. Where barriers are put in place to restrict such collaboration the Net Geners use social networks to convey their concerns.

This heralds a new approach to publication of research output. Whilst the main stakeholders argue over the merits or otherwise of promoting 'free access' to research output, the more challenging need is to provide end users with what they need in a format which is wanted, in a manner which is interactive and collaborative, at a price which is acceptable, and within an overall context which enables all participating stakeholders to achieve a reasonable and sustainable financial return. This affects academics as much as UKWs – resolution of the access problem could have benefits for the whole research community.

5.10.2. Demographic data on UK researchers

The numbers of UKWs continues to grow. The following chart shows the distribution of new entrants to various trades and occupations from graduates of UK universities (HESA, 2014). It shows how significant the professions are in attracting newly qualified graduates. Professions are a key sector in expanding the UKW numbers in UK society.

Graph 5.5. Employment by Standard Occupational Classification % Male Leavers to fulltime occupations, 2012/13



Source: HESA, 2014

To quote from an article by Park (CEO of DeepDyve, a Silicon Valley-based company selling published articles to individuals irrespective of their affiliation):

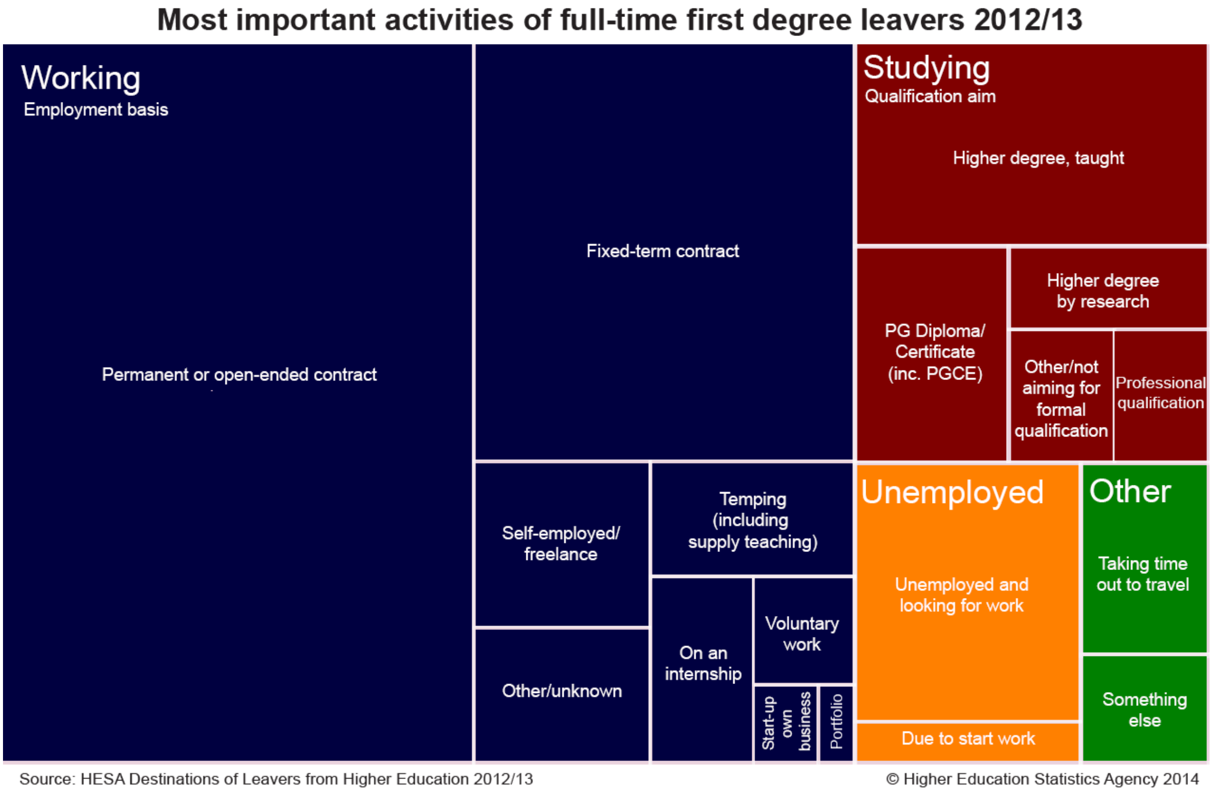
> "In 1930, 25% of the US population of 122 million lived on farms and only 3.9% of the population had a college degree. Fast forward to 2006: just 2% of Americans live on farms, the US population had nearly tripled, 17% of Americans held a bachelors degree and nearly 10% a graduate degree" (Park, 2009).

There is a growth in the proportion and number of an educated population of 'knowledge workers' within society as UK and other governments seek to increase attendance rates at higher education institutions. This leads to a more informed and ‘scientific aware’ society, and as such is a stimulus for wider dissemination and understanding of scientific research results beyond traditional academic/research boundaries.

Targets set by successive governments in the UK, whereby college and university trained students increase as a proportion of British society, supports this trend towards greater scientific awareness. Though graduate enrolment of 49% of the population has been claimed in a UKDBIS report, the actual percentage is nearer 35% (Ball, 2013). In 2011 there were 20,076 PhDs awarded - this represents the fourth largest producer of PhD graduates globally. The volume of PhDs is an indicator of the country’s new talent on tap. A commitment to raising educational attainments in both developed and developing countries also creates an environment within which the dissemination of relevant research results is a more fertile ground than that which existed in earlier decades.

The increase in the proportion of knowledge workers within UK society is occurring faster than that for academics or for those in corporate R&D. This is fuelled by the growth in graduate and postgraduate outputs from the higher education system, with far more going into private service than remaining in academia on completion of their studies. This is indicated in the following table made available by HESA.

Graph 5.6. Full time first degree leavers 2012/13



There is a distinction in employment patterns according to discipline – in medicine and dentistry 92.2% go straight into the workplace, whereas the subject generating the greatest numbers going into further study (32.3%) is law. Nevertheless, paid workers outside further study (academia) are numerically almost five times greater than those graduates remaining within academia. Each year the 'tail' of knowledge workers (of which UKWs are a subset) gets larger. The flow of people through higher education and into a career can be categorised as a 'pipeline' of talent but one that narrows as individuals pass through it and are 'siphoned off' into careers outside academia (Elsevier, 2013).

The following table gives a more detailed breakdown in the split of graduates between fulltime employment and further study by occupational discipline in 2008/9.

Table 5.10. UK output of graduates into knowledge-based occupations, 2008/09

Profession	**Numbers overall**	**Paid work Numbers**	**Paid work %**	**Further study numbers**	**Further study %**
TOTAL	291,475	142,670	48.9%	39,735	13.6%
Industrial & Engineering					
IT strategy and planning					
Civil engineers	}				
Mechanical engineers	}				
Chemical engineers	} 12,705	6,245	49.2%	2,225	17.5%
Design & Develop eng	}				
Electronic engineers	}				
Production & Process	}				
Planning & quality	}				
Quantity surveyors					
Bioscientists/biochem	25,105	9,955	39.7%	5,685	22.6%
Physicists, geologists	12,210	4,780	39.1%	3,455	28.3%
Sub Total	50,020	20,980	41.9%	11,365	22.7%
Services					
Medical professions	34,985	25,205	72.0%	2,725	7.8%
Dentists					
Opticians					
Software professions	9,840	4,475	45.5%	1,695	7.2%
Solicitors, lawyers	12,195	3,940	32.3%	4,505	6.9%
Legal professions nec					
Management, business					
Managt, accountants	26,850	13,075	48.7%	3,450	2.8%
Psychologists	10,130	4,320	42.6%	1,750	7.3%
Social science research	24,345	11,530	47.4%	4,110	6.9%

Social workers					
Probation officers					
Public service					
Architects	6,410	3,050	47.6%	1,140	7.8%
Town planners					
Veterinarians	665	535	80.5%	30	4.5%
SubTotal	125,420	66,130	52.7%	18,265	14.6%
TOTAL of Above	175,440	87,110	49.6%	20,990	12.0%

Source: Higher Education Statistics Agency (HESA). 2014. *Higher Education – Statistics for the United Kingdom*. HESA. June 2015

The key point is that of the 430,000 UK graduates in 2009, only 14% stayed on to become 'privileged' or 'affiliated' scientific information users whereas the majority took employment in various professions and businesses in the UK, both public and private, and in effect became potential UKWs.

The following table gives a breakdown of the disciplines/professions which took graduates as first time employees in 2011/12.

Table 5.11. Destination of UK University leavers who obtained first degrees by subject area and activity 211/12

Discipline	**FullTime Work**	**PartTime Work**	**FullTime Study**	**PartTime Study**
Medicine & Dentistry	6,615	30	390	10
Subjects allied to Medicine	13,425	2,495	1,510	95
Biological sciences	10,195	4,325	4,820	315
Veterinary sciences	525	20	10	0
Agriculture & related subjects	950	305	190	25
Physical sciences	4,605	1,190	3,055	145
Mathematical sciences	2,200	370	1,140	50
Computer sciences	5,185	900	750	55
Engineering & technology	7,045	985	1,635	95
Architecture, building	3,080	505	450	35
Total Science	*53,725*	*11,125*	*13,945*	*820*
Social studies	11,465	3,310	3,230	245
Law	3,470	1,090	3,105	195
Business & administration	15,860	3,280	2,215	250
Mass communications	4,045	1,595	435	65

Languages	7,025	2,290	3,180	195
History/Philosophy	4,820	1,710	2,655	190
Creative arts & design	12,770	6,715	1,945	275
Education	7,085	1,655	1,160	75
Combined studies	375	115	110	3
Total all subjects	*120,635*	*32,885*	*31,970*	*2,315*

Source: Destinations of UK Domiciled leavers who obtained qualifications through fulltime study, HESA, 2010. (Data for 2008/09. (Table 3a))

Nearly 50% of the leavers were in the sciences (half of which were in life sciences), with business studies, social science and creative arts also figuring as important contributors to the UK knowledge economy. These percentages leave their mark on the skill set which is available within the private sector and among UKWs.

5.11. Culture

An aim of this thesis is to identify those social trends which determine how changes take place in the information sector. It is contended (see 6.3) that STEM publishing is not robust. It does not serve users of research output well. It is restrictive, limiting usage to an institutional clientèle, preventing the individual researcher who may also be on the fringes of the research effort from having easy access (see following chapter on the Dysfunctionality of STEM).

In making these claims it is emphasised that there is no universal culture common to all scientific disciplines. Each discipline has its own peculiarities shaped according to circumstances deep within the science itself and the community which built up around it. There are also individual's circumstances – personality, ability to adapt to change, having access to funds, confidentiality issues – which are determinants at grass roots level impacting on an individual's willingness to adapt to change.

A powerful feature of the emerging culture of science is the extent of networking activity which is taking place and which places emphasis on 'cooperation', 'sharing' and 'collaboration' to an extent not seen in the print era of scientific communication. Not only is this evident in 'Big Science' (Price de S, 1963) and highlighted in international projects such as the Large Hadron Collider (LHC) project, but is also seen in the changed working practices of researchers in other disciplines and in some instances in the activities of the general public. The process of organising many researchers from all walks of life and from around the globe requires a skill set different from that required under the former practice of 'little science' research.

If organised effectively, it attracts wide community participation focused on a research topic, and in so doing brings in unaffiliated knowledge workers as well as the affiliated – especially where a diverse skill set proves valuable in tackling the topic.

However, such changes in culture and working practices raise new questions. Can the organisation of these emerging collaborative networks ensure common procedures, standards and acceptable practices are adopted by all participants in the network – both academic and non-academic? What inducements or sanctions can be imposed to ensure consistency and quality by all those active within these new research networks? This is a question currently also confronting large established professions as they face decomposition (Susskind, 2015).

A further question is the extent to which researchers in front-line research in academia and the corporate world are prepared to open up their research activities to those who do not have the experience or qualifications which are entry conditions to scientific research. Whether they can become active participants in the research team. Whether a broader platform of research provides sufficient additional benefits to compensate for the added effort in creating a network of participation and ensuring that it operates effectively.

There are therefore questions about how much trust and faith there is in both the established – print journal based system – and the new informal digital communication systems by those who are actual users, and perhaps more significantly, those who are still latent and potential users. What judgements are used to decide how much credibility to give different forms of published output? Some of these issues were addressed by an investigation funded by the US-based Sloan Foundation and including the University of Tennessee, CIBER, and several publishers. The study involved assessing behaviour patterns and wishes among scholars and was completed in November 2013 (Tenopir and Nicholas, 2014; Nicholas et al, 2014a).

No firm conclusions can be drawn on how cooperation and collaboration will develop in a fully digital STEM world. The underlying informatics structures suggest that openness and wide participation will emerge, but it is unsafe to speculate at this stage how the sociology of science will change and whether a fully UKW-embraced culture will emerge and when.

5.11.1. Cultural adaptation

It is nevertheless a common theme among industry observers that greater democratisation will occur in the provision and access to information. Changes in the entertainment and consumer sectors will spill over into the STEM communication arena, and result in further changes to acceptable modes of scientific communication taking place in future (Esposito, 2012a).

The focus has become on how users of publications are altering their habits along with the new information environment. Authors such as Gladwell ("the Tipping Point", 2000), Anderson ("The Long Tail" and "Free", 2009), Surowiecki ("Wisdom of the Crowd", 2004), Nielsen ("Collective Intelligence", 2011), Weinberger ("Everything is Miscellaneous", 2007, and "Too Big to Know", 2012), Tapscott ("Growing up Digital", 1998; "Grown up Digital", 2008, and co-author of "Wikinomics", 2006), Shirky ("Here comes Everybody", 2008), Weller ("The Digital Scholar", 2011), Carr ("The Glass House", 2016) are some of the many writers who have pointed out that technological developments have an impact on research output, researcher activity and the underlying sociology of science. This in turn has affected user behaviour which in turn raises the question of the role of a knowledge worker community in the new and evolving digital information economy.

It has led to writers and researchers such as Neilsen (2011), Monbiot (2011), Gowers (2014), Brown A (2009), Allington (2013) and Murray-Rust (2014) suggesting that the current STEM publishing system is no longer fit for purpose and needs to be changed to cope with new socio/technical conditions (see section 4.1.2).

One significant development was the introduction of the concept of Long Tail. The long tail (Anderson, 2004; 2009a) claims that Internet channels exhibit significantly less sales concentration compared with the 80:20 concentration traditionally held under the Pareto Principle for print. Evidence is available to support the contention that the Internet's Long Tail has dramatically changed the business profiles of many items available on the Internet.

The long tail can also be applied to the audience profile for scientific research output, with researchers in academia being the 'core', and UKWs being part of the 'tail'. In many industries (music for example) the tail exceeds the core in size and significance. It can also be applied to the output of STEM publications, with a few core articles and many specialist and esoteric reports in each research field (see 6.4.1.4).

There have also been studies which highlighted generational differences in science communication. The so-called 'X', 'Y' and 'Z' generations, or distinguishing between the Net Generation (Net Gens) from those who preceded the arrival of the Internet. Whilst it is not clear the extent of the changes created by these generational differences, it does appear that those academics and professionals who are starting their careers both within and outside the higher education system have different propensities to adopt digitally-delivered information from those who have been brought up in an era where print-only dominated. Effects of having grown up on a diet of interactive games, smartphones, iTunes and online systems in formative years has now made it easier for them to accept alternative, digitally-based, STEM information systems.

Those who grew up before the 1980's still rely - by and large - on in-depth reading of research articles to satisfy their information needs. Those who grew up after the 1980's engage in multimedia activities and multi-tasking. The jury is still out on some aspects of these claims, but if endorsed, will have a bearing on how the changing social needs generally can be mapped onto specific needs of unaffiliated knowledge workers. Monitoring researcher behaviour patterns through longitudinal studies becomes a critical task.

Concerns remain about how social media will impact on researchers. As quoted by Greenfield, "Social networking sites could worsen communication skills and reduce interpersonal empathy; personal identities might be constructed externally; ... obsessive gaming could lead to greater recklessness, a shorter attention span and an increasingly aggressive disposition; heavy reliance on search engines and a preference for surfing, rather than researching, could result in agile mental processing at the expense of deep knowledge and understanding" (Greenfield, 2014 p 279/80). Meyer (Meyer) also challenges the role of multi-tasking. It results in less deliberative thought, less being able to think through a problem. Multi-tasking involves spending too much time on distractions which preclude entering the quiet space for contemplative thought. It remains to be seen whether the Greenfield and Meyer arguments turn out to be more accurate than those put forward by Shirky (2008), Weinberger (2007), Tapscott (2008), et al who focus on the benefits from using informatic services online..

In a related vein, Lieberman has explored an individual's need to connect with other people, a fundamental need he claims as basic as that of food or shelter (Lieberman, 2013). He asserts that because of this our brain uses its spare capacity to learn about the social world – other people and our relation to them. It is believed that we must commit 10,000 hours to master a skill - see "The Outliers" by Gladwell *(*Gladwell, 2008). According to Lieberman, each of us has spent 10,000 hours learning to make sense of people and groups by the time we reach ten years of age. Sharing, cooperation, collaboration – key aspects if UKWs are to be engaged in the research process – have their groundings in sociological processes developed in youth. 'Sharing' of information has become a critical aspect in the digital/Internet world and for scientific research. The brain has evolved sophisticated wiring for securing individual's place in the social world. This wiring often leads to restraint on selfish impulses for the greater good.

Another impact which the social context is having on the individual's ability to adapt to a new digital information environment was put forward by Nicholas Carr as an extension to "The Shallows" arguments. In his later book, "The Glass Cage" (Carr, 2016) Carr describes how those who determine developments in automation, through software developments do so to achieve efficiencies and not necessarily in support of broader cultural values. In effect he suggests we are increasingly devolving many creative and innovative processes onto the machine and away from human control. “The computer, introduced as an aid to reduce the chances of human error, ends up making it more likely that people …. will make the wrong move” (Carr, 2016 p 92).

5.12. SOCIAL MEDIA

Meanwhile, reports suggest that large sections of UK society join online networks, ranging from personal interest groups to corporate research networks, in order to find information, solve problems, build new services, or forge new relationships (Tapscott, 2008; Shirky, 2008). Participation in Wikipedia-like services, seeking and disseminating knowledge freely for everyone, has become popular.

5.12.1. Adoption of Social Media within Society

This is in part because in recent decades social media services have exploded onto the scene – having been marginal or non-existent a decade or so ago. The extent of the increase in social media use and the ability to move between the various platforms has opened up new approaches to undertaking background research.

The following table illustrates just how intricately involved social media has become in 2015 at a global level.

Table 5.12. Summary of Social Media penetration, 2015

Summary (Jan 2015)	**Numbers users**	**Percent of total**	**Year-on-year growth**
World total Population	7,210 million	100%	+1.6%
No. Active Internet users	3,010 million	42% penetration	+21%
No. Active Social Media accounts	2,078 million	29% penetration	+12%
Number Unique Mobile users	3,649 million	51%	+5%
Active Mobile Social Accounts	1,685 million	23%	+23%

Sources: Statistics from news reporting sources including *The Times Business dashboard*, November 30, 2011. Also from Statistica, The Statistical Portal (Statistica, 2015)

The rise of social media and social networking has been particularly dramatic within the consumer and entertainment sectors of UK society. It has changed the information profile and activity of consumers. The respective impacts on research are described below.

Methodology

Data on social media services listed below was collected from a variety of published sources and online services as well as from the web sites of the main social media services. The data indicates the scale of the service concerned though the figures provide little indication of the intensity or regularity of use, particularly in a STEM context.

Table 5.13. Numbers of users per Social Media

	USERS			*CONTENT*	*VALUE*	
Social Media	***Geographical coverage***	***UK users***	***Global users***		***Corporate value ($)***	***Mobiles***
Facebook	Global	35 mil (8/15)	1.44 bil (6/15)	30 bil content items p/m	Advert Revs 2015 $14.3 bil (est)	
Google	Global		300 mil active users p/m 187 mil visitors (03/4)	1.17 bil online searches p/m (11/13)	$2.3 bil (2004)	20 mil users p/m (10/13)
Yahoo			1.0 bil members		$19 bil (2011)	139 mil phone users
LinkedIn	50% USA 60% academic	15 million (8/15) of which 2.3 mil in London. Students key driver for growth	364 mil members (2015)		$2.2 bil (2014)	
Twitter		9.5 – 15 mil (rosemcgrory.co.uk) 50% in 18-34 age (www.emarketer.com)	302 mil active users (04/15) 36 mil visitors p/m (09/13)	300 mil Tweets (03/15)	$23 bil (2014)	
YouTube		19.1 mil monthly visits from UK (09/13)	1 bil users	4 bil video views p/day	$4 bil (09/13)	500 mil mobile users
Instagram	776 mil users in USA (2015)		300 mil monthly active users		$1 bil paid by Facebook (2013)	
MySpace	432 mil US visits		50.6 mil monthly users (01/15) 90% are under 35.	300 mil monthly videos viewed	Acquired for $580 mil (07/05)	
Q-Zone	China		644 mil users (05/14)			

Mendeley	31% biomedics		2 million users (11/12)		Acquired by Elsevier (2014)	
Wikipedia			25.5 mil users	5 mil articles (750 p/d)	Seeking financial model	

- *Facebook*

Facebook has revolutionised the way growing number of digital users communicate. There were 1,440 million active *Facebook* members (June 2015) – one in seven of the world's population. An additional 2 million sites link in with *Facebook*. 35 million users were in the UK alone (source: Twitter item on Facebook, 24 August, 2015). It began as a free but closed system, and generated a club-like adherence from dedicated users, away from the general search engines. *Facebook* became a parallel universe to the Web. Though advertising has not been monetised as much as Google (US¢ 40 per month per visitor for *Facebook* compared with *Google*'s US$ 2.11) investors have bought into Zuckerberg's entrepreneurship in the IPO (initial public offering on the stock exchange) which gave him control in 2015 over voting rights as well as remaining CEO and being founder of *Facebook*.

- *Google*

Google has also dominated the way both affiliated and unaffiliated knowledge workers search for relevant information. The number of monthly unique *Google* searches was 1.17 billion (November 2013). This gave *Google* a 75% share of the online search engine market. There were 300 million monthly active users of *Google*+ and the number of *Google*+ unique 'mobile' monthly users was 20 million (October 2013). Global number of Gmail users has been put at 900 million (source: *Google* web site, October 2013)

- *LinkedIn.*

During the first quarter 2015 *LinkedIn* had 364 million members, up from 296 million the year earlier. It is a professionally-focused media platform and therefore a target for UKWs. In 2014 most revenues came from talent solutions, online recruiting, marketing solutions and premium subscriptions. In the UK the main categories of *LinkedIn* users in 2015 were:

* 12,530 journalists
* 48,679 solicitors
* 374,711 engineers
* 4,083 farmers

These categories give some indication of the spread of UKWs in the UK using one of the social media platforms. In the meantime LinkedIn has been acquired by Microsoft in June 2016.

- *WhatsApp*

Over 1 billion users claimed for *WhatsApp* users worldwide in media reports in early 2016.

- *Twitter*

In January, 500 million tweets were sent per day by 302 million active users (April, 2015). Though 30,000 people a day were signing up to tweet, this did not match market expectations.

- *YouTube*

YouTube has over 1.0 billion users. Half of *YouTube*'s views are made using mobile devices (smartphones, laptops). The company generated $4.0 billion in revenues, and projected 4 billion video views per day. The number of monthly unique visitors to *YouTube* in the UK amounted to 19.1 million (September 2013).

- *Instagram*

There are 300 million Instagram active monthly users. The number of US-based *Instagram* users in 2015 was 77.6 million or 28% of the US population. 13% of Internet users use *Instagram. Facebook* paid $1 billion for the company in 2013. There has been a rapid growth in the photo-based Instagram to the extent that it is challenging the text-based *Facebook* and *Twitter* for acceptance (according to Radio One broadcast, December 2014).

- *QZone*.

QZone has 644 million active users, the majority of which are based in China (May 2014). It now accounts for 40% of the world's social media users.

- *Mendeley.*

As of November 2012, *Mendeley* had 2 million users. 31% were in biosciences and medicine and 16% were from the physical sciences. 13% were engineers and 10% computer and IT specialists. On average each user collected 142.8 papers and spent 1 hour 12 minutes per day studying the literature (Mendeley, 2012). The company was acquired by Elsevier in early 2014.

- *MySpace.*

Started in August 2003, it was acquired by Rupert Murdoch (News International) in July 2005 for $580 million. It was bought by Specific Media/Justin Timberlake for $35 million in 2011. It has 150 employees (January 2015), well down from its peak of 1,600 employees a decade earlier. There were 300 million monthly videos viewed from 50.6 million monthly users (January 2015). Though it was overtaken by *Facebook* in April 2008, *MySpace* remains an important web property.

- Wikipedia

A 'wiki' (from the Hawaii word for quick) is a web site that users can directly alter or add to. The most popular example of such a web site is Wikipedia. Wikipedia includes 35 million articles which are being added to by 750 new articles each day by approximately 69,000 main contributors. The number of registered users is 25.5 million creating an estimated half a billion usages each month. It is a prime example of a collective project in which participants seek no direct financial gain.

Summary

Social networks are now ubiquitous. Based on the self-reporting of over 2,000 individuals over 12 years of age in the USA (Arbitron 2013), the percentage of persons using each of the main social networking services was summarised as follows:

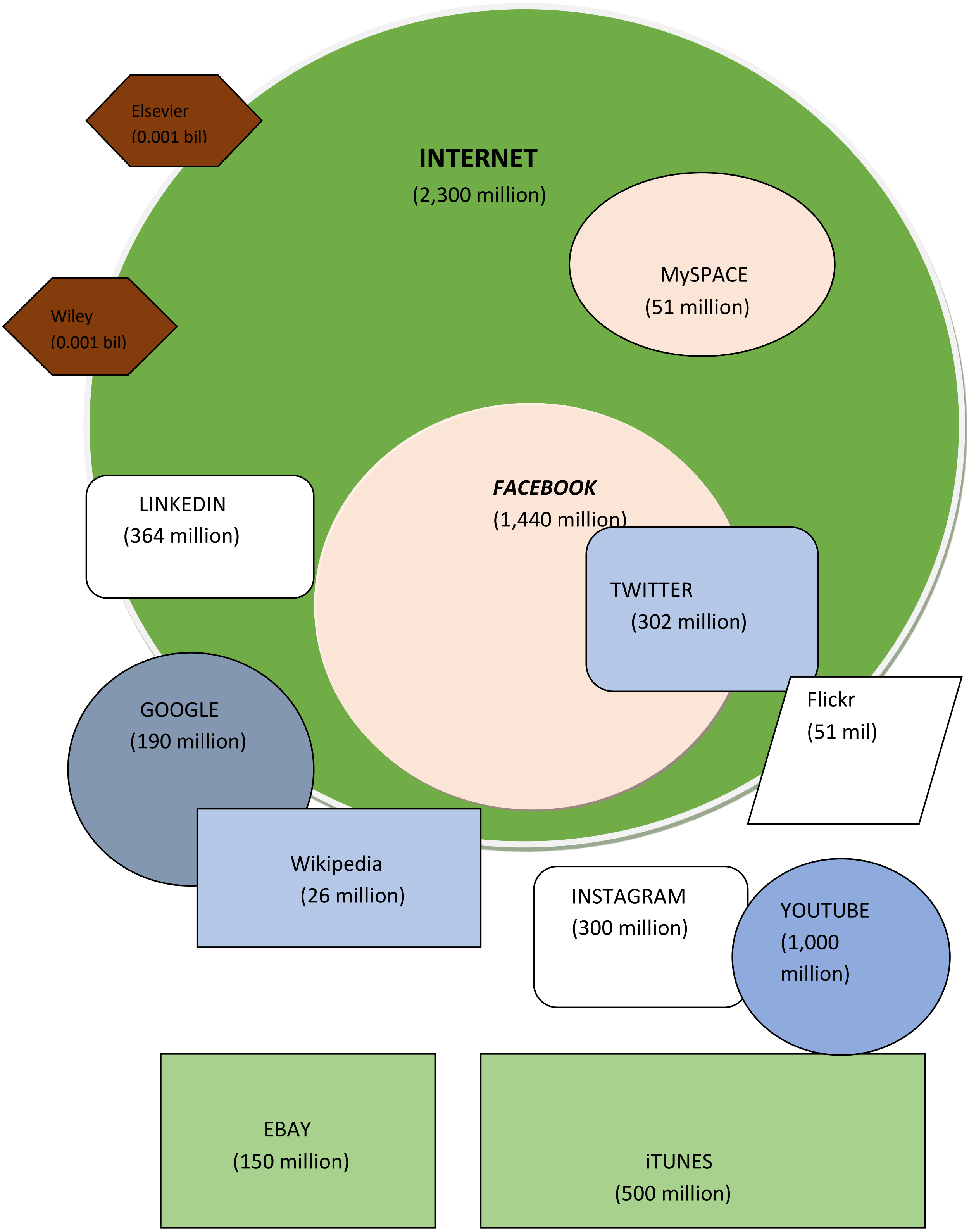
FaceBook	*58%*
LinkedIn	*17%*
Twitter	*15%*
MySpace	*14%*
Google	*12%*
Instagram	*12%*

Pininterest	*10%*
Tumblr	*4%*

These usage percentages represent a wider community – one in which UKWs inhabit – rather than just the STEM audience. For example, *Google* usage would figure more prominently in the research community, and *FaceBook* would not be so dominant in the exchange of STEM material. Nevertheless, the indications are that social networks need to be taken into account in the future evolution of the STEM information system.

The following chart illustrates how several of the main social media services relate to the Internet. It highlights that the numbers of users to each of these services are in the millions – a revolution in the way individuals are communicating in the Internet/digital world. It also puts into perspective the small inroads which the large commercial journal publishers have made in developing STEM-related activities as a service supporting global digital natives.

Graph 5.7. Social media services

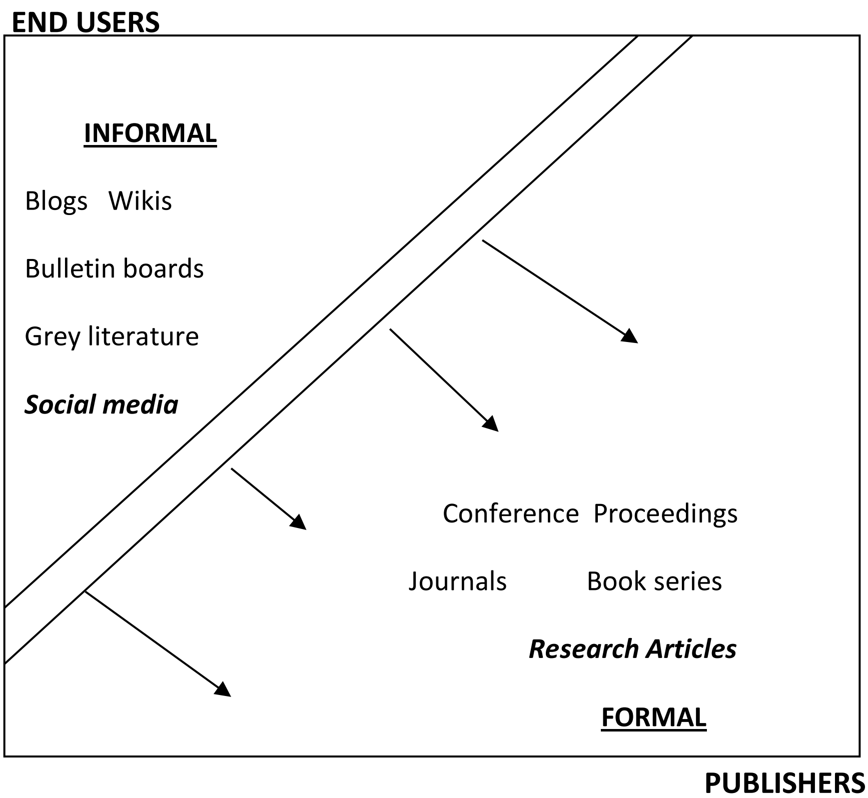


Thus far conservatism in STEM authorship has been a powerful factor protecting the established print-derived paradigm. The traditional system has been reinforced by the existing reward system which in turn is mainly evaluated and assessed through citation metrics. The effectiveness of *authors* in research is judged on whether their output appears in the highest cited impact factor journals. *Users* of research output have followed the lead of authors and rely on the published research article in a reputable journal as their main source for credible information.

This means the social media revolution which has swept through the entertainment and general interest areas – areas in which UKWs are also often active – has not yet impacted significantly on the specialised STEM publishing sector.

Nevertheless, the following graph shows how social media will erode into print-based publications, driven by the tsunami of external, environmental agents for change.

Graph 5.8. Impact of informal communication on traditional STEM publishing



5.13. RESEARCHER BEHAVIOUR

Methodology

Several industry reports, including grey literature, have been analysed for this chapter – providing a quantitative data to complement the overall qualitative assessment of STEM and UKW users.

The studies which are referred to are either recent or backward-looking. They are based at best on assessing researcher behaviour using log analyses to follow their online 'exhaust trails'. At worst they rely on impressions of past experiences reported by individual researchers which give little indication of what the information needs and habits of researchers in a future digital age might be.

Several studies focus on the structure of the research community, mainly the typology of research behaviour. These are included in this assessment as they could indicate structural issues which non-academic researchers might bring with them in coming to terms with digital information systems.

5.13.1. Typology of Researchers/Users

Studies undertaken in the past apply typologies to individuals according to their ability to interact with published scientific information in whatever format. The profiles vary from the totally switched off to those who become gatekeepers, selecting, filtering and redistributing information on behalf of colleagues. The latter are the 'mavens' (see 'Tipping Points' in section 6.4.1.4, and (Gladwell, 2000)).

In demonstrating that researchers have different needs for access to STEM information, such typologies can be applied to the latent audience for STEM – the UKWs. If the same structures can be applied to the UKW audience, this might indicate the proportional distribution of user types in the various still latent UKW communities. It stresses that a single approach to embracing the UKW audience would not be realistic – segmentation of the UKW communities in terms of disciplines, culture, and user typology would be necessary.

5.13.1.1. The SuperJournal project

An important study on researchers' typology, funded jointly by Jisc and several STEM publishers, was the 'SuperJournal' project (Pullinger & Baldwin, 2002). The structure they identified for researchers adapting to e-journals was based on questionnaire returns received from 2,500 users. This created a database from which two main types of users were identified — regular users and occasional users. Within these two categories a number of user types were identified.

Table 5.14. Profile of users in Superjournal project

Regular Users	Enthused	*Frequent use of large numbers of journals (at least 11.6), usually of the full text. Mainly social scientists. There were 16 users in total.*
	Journal-focused	*Very frequent use of specific journals, half their time being spent on the full text. 92 were identified.*
	Topic-focused	*Access titles once every six weeks or so. Use on average 3.5 journals. More social scientists than natural scientists. 218 users in total.*
	Article-focused	*Access once every two months. Use only one journal, sometimes reaching into the full text. Mainly natural scientists retrieving known articles. 434 in total.*
Occasional Users	Bingers	*Used service for short period of time, intensively, and did not return.*
	Explorers	*Used the online service extensively, making several repeat visits.*
	Window shoppers	*Those who came into the online service, looked around, and then left. Mainly natural scientists.*

Other typologies have been identified in different studies. The first systematic attempt at typology of researchers was by the Faxon Institute in 1991/92. Their unpublished multi-client study showed that almost 50% were either 'information zealots' or 'classic scientists' and 16% were 'information anxious' (Faxon Institute, 1991/92). More elaborate typology of all sections of the US community, not just researchers, is undertaken at regular intervals by the Pew

Internet and American Life project. Ten different typologies were identified, ranging from ‘Omnivores’ through ‘Lackluster Veterans’ to ‘Indifferent’ and ‘Off the Network’ (Pew, 2008).

Targeted analyses of STEM researchers have been made by Professors King and Tenopir in the United States. Typology was not the key feature of their many reports but rather an assessment of use often based on critical incidence feedback.

5.13.1.2. Patterns of STEM Use

The main results from the investigations undertaken by King and Tenopir can be summarised as follows:

Table 5.15. Understanding Patterns of STEM Use

Readings per researcher		No. of articles	No. of Hours
	In academia	188	180
	In Industry	106	88

From Journal Subscriptions	Year	Personal subscription	Library collection
	1977	60%	25%
	1990/3	36%	54%
Age of article read	Over 30% from journals over 1 year old		
Time spent on Research	Hours spent on all research activities		2,400 per annum
Type of Document read	Format	University researcher	Non University researcher
	Research journals	188	106
	Trade journals	74	51

	Professional books	48	53
	External reports / grey literature	20	12
	Internal reports	26	53
	Other materials	14	22
	Total	370	297

Disciplinary differences	Discipline	Average number of articles read per annum
	Medical researchers	380
	Paediatricians	180
	Engineers	75-111
	Social scientists and psychologists	191

Tenopir and King based their reports on responses received from over 25,000 scientists, engineers, physicians and social scientists during the past thirty years. These represent academic-affiliated researchers. During this period the average number of articles read by these largely university-based scientists has risen from 150 (1977), to 172 (1984), to 188 (1993) to 216 articles between 2000 and 2003. This is not consistent across disciplines, as shown above.

Tenopir/King also established that during the same thirty-year period the average number of personal subscriptions which individuals took fell from nearly 6 to under 2. This was compensated for by access through library central holdings and interlibrary support services (Tenopir & King, 2000).

As with similar studies, these throw little light on the intensity with which researchers will make use of the many new alternative digital formats in future. They serve as excellent bases for operational purposes, but not for providing aids for formulating strategies to embrace the digital researcher and those researchers in wider knowledge worker sectors.

5.13.2. Ofcom

The Office of National Statistics commissioned a study conducted by Ofcom, the UK government's telecommunications watchdog, in August 2014. The results gave a picture of how the young generation have adapted to new communication technology in the UK.

According to Ofcom the advent of broadband in the year 2000 has created a generation of digital natives. "These younger people [children] are shaping communications," claimed Rumble, head of Ofcom's media research. "They are developing fundamentally different communication habits from older generations, even compared to what we call the early adopters, the 16-to-24 age group" (Ofcom 2014).

Millennial children contact each other and consume entertainment differently from previous generations, and industry pundits consider their preferences a better indicator of the future than those of innovative young adults. The most remarkable change is in time spent talking by phone. Two decades ago, teenagers devoted their evenings to using home telephones. However, for those aged 12 to 15, phone calls now account for about 3% of time spent communicating. For all adults, this rises to 20%. Today's children do a majority of their remote socialising by sending written messages or through shared photographs and videos. "The millennium generation is losing its voice," Ofcom claims.

Over 90% of their device time is message based, chatting on social networks such as *Facebook*, or sending instant messages through services such as *WhatsApp*, or even sending traditional mobile phone text messages. On the other hand, 2% of children's time is spent emailing — compared with 33% for adults.

Away from their phones, 12 to 15 year olds have a different relationship with other media. A seven-day diary showed live television accounts for just 50% of viewing for this age group, compared to nearly 70% for adults. They spend 20% of their time viewing short video clips, for example on *YouTube*. Young adults aged 16 to 24 are active consumers of almost all media, devoting 14 hours and seven minutes each day to communications, if the time spent multi-tasking, for example texting while watching TV, is included. However, their use of radio and print based media has all but disappeared.

Such change in behaviour patterns is critical at all ages, but particularly among the generation which will soon feed into the nation's research efforts. Not only will it affect the way future academic researchers are able and willing to conduct their communication activities, but it will also set new demands (by UKWs amongst others) to modify the communications systems and infrastructure to allow them to become active participants in research whatever their institutional affiliation.

5.13.3. Gaps and Barriers

A study into the difficulties facing users in accessing research output was undertaken by CIBER (Rowlands and Nicholas, 2011). In this study, journal articles were considered critical to discovery. Nevertheless, 11.5% of all researchers described their current level of access to journal articles as `poor' or `very poor'. For university researchers, the proportion fell to only 5.4% but rose to 19.8% in the case of knowledge workers in small and medium-sized enterprises and 22.9% in manufacturing.

Faced with barriers to access, the general response was "simply to give up and find something else" which does not auger well for efficiency and productivity. The study also pointed out that "there are around 1.8 million professional knowledge workers in the UK, many working in R&D intensive occupations (such as software development, civil engineering, consultancy) and in small firms who are currently outside of subscription arrangements. The needs of this sector of the economy demand greater policy attention".

The UK industrial sectors reporting the poorest levels of journal access included the motor industry, utilities companies, metals and fabrication, construction, and rubber and plastics, although, clearly, R&D takes place in these industries.

In the CIBER study, nearly half (45.8%) of the researchers reported that they had difficulty accessing the full text of journal articles they needed on ten or more occasions over the previous twelve months (Rowlands, 2011). It is not possible to quantify the knock on effects of this `failure at the library terminal'. A spectrum of outcomes is possible, from mild frustration to more serious outcomes such as repeating an experiment unnecessarily or losing out on a grant.

There is also confusion about licensing and particularly walk-in rights, especially for accessing e-resources. Pay-per-view business models constituted a disincentive to accessing research publications. There was widespread reluctance to pay for individual articles at prices currently being asked for by publishers and document suppliers, and a minority of researchers (26.3%) claimed that they had strong objections in principle to this mode of access.

Nevertheless, there were indications of a substantial market for pay-per-view and that this could grow further if acceptable business models could be found. 12.6% of respondents to the CIBER survey say they might consider buying individual journal articles in the future, and this proportion rises to 43.8% in the case of conference papers.

What is clear is that the same researchers have different voices depending on whether they are looking at STEM access from a reader's or an author's perspective. The two are by no means synonymous.

5.14. RESULTS FROM RESEARCH AND ANALYSIS

In addition to the review of printed literature – both formal (refereed) and informal (social media) – several other research analyses were conducted in non-literature areas. These included a survey of available datasets and online interviews using a questionnaire approach.

These were related to Results for the UKW described in this chapter – other research actions undertaken during this project are described in the chapter describing Results on STEM Dysfunctionality (see chapter 6) and Learned Societies (chapter 7).

5.14.1. Results from data analysis

In the UK there are few examples where knowledge workers are allowed occasional and easy access to STEM material. Nevertheless, the Office of

National Statistics (ONS) provided statistical data on the size of some of the potential ‘unaffiliated knowledge worker’ audiences – over 11 million in total.

In addition to which, the demographics are dynamic, with more UKWs increasing each year from higher education institutes which is creating a fire hose of latency for STEM-related issues. The Higher Education Statistics Agency (HESA) provides tables based on sampling of graduates and postgraduates to determine their destination in either academic or private sector employment (HESA, 2010; 2014). This data shows that over four times as many graduates and postgraduates leave academia (to become potential UKWs) as remain within higher education. The issues facing UKWs become more important as UK society becomes more science-trained and scientific-aware.

Statistics on the numbers of practising professionals were obtained from an industry directory on trade and professional associations (CBD, 2009) which show the range of professional associations which exist and the numbers of individual members involved. This again exposes the gap between those entitled to receive STEM as a right from those who have no access rights even though they might benefit from easier access.

Government interest in STEM developments is indicated in the ‘scoreboard’ data which the UK Department of Business, Innovation & Skills (UKDBIS, 2009) has produced. However, statistical sources which give evidence on the breach in the scientific communication system are neither sophisticated nor consistent. The Office for National Statistics (ONS, 2011) gives an indication of the extent of ‘knowledge workers’ in the UK without providing insight on those who rely on research data in their daily occupations. UKDBIS’s Scoreboard gave some additional, non-comparative, data. Another insight into the demographic trends involving researchers comes from the Higher Education Statistics Agency (HESA, 2010; 2014) in their ‘Destinations of Graduates’ data.

Correspondence was entered into with the Office for National Statistics (ONS) to establish what data relevant to this project was available from this public body. Knowledge workers are a defined category in their data collection, but it is a broad definition of knowledge workers encompassing all forms of scientific with non-scientific activities (see section 5.3).

Data from other countries were also analysed to see whether they offered insight into the structure of the STEM industry. This included the National Science Foundation in the USA (NSF, 2010a; 2010b; 2014) which publishes data about the US public research sector but offers little indication of the situation facing UKWs. Unesco produces, every five years, a Science Report which gives comparative data on education and science around the world (Unesco, 2010; 2015). OECD also makes financial data available for its member countries (OECD, 2008; 2015).

5.14.2. Results from Phone Interviews

Two studies of researchers' information needs were conducted at an early phase in this project. Both involved small samples of the research universe. The first was at the start of the project to inform the Research Questions which were set for the thesis, and included seventeen respondents. The second, two years later, focused on the emerging digital information needs, and included twenty participants.

Each study represented snapshots of researcher opinions. A semi-structured interview approach was adopted and reports were written after each phone interview. These were not longitudinal studies as the questions in the two studies were slightly different, though both aimed at identifying researchers' perceptions of aspects of the changing STEM scene. The results confirmed earlier held assumptions that there was concern about the STEM publishing industry in its current form at the individual researcher level. A discourse analysis was adopted in assessing the phone interviews.

Whilst it is accepted that discourse analysis/conversational analysis "can make significant contributions to the systemic study of human systems (Gale, 2010 p 31) it is just one point-of-view of many perspectives for understanding human meaning making". However as part of a multifaceted approach to researcher understanding this research phase has value.

5.14.3. Results from Meetings and Interviews

Twenty one-to-one meetings were held during this thesis, during the period September

2009 to June 2014. Several involved discussions with agencies related to the UKW issue (see below) and several with agencies focussing on STEM developments. The UKW-related meetings raised the following issues:

- The role of ALPSP, as a consortium of learned publishers was investigated during a meeting with its deputy director (who has since become its chief executive). It became clear that operational issues dominate discussions within ALPSP membership. A cooperative strategic approach among member organisations, found in other industries, is lacking within learned societies. Partly because of their size/scale, and partly because their publishing operations are only one of a number of functions performed by the learned society, there are few instances where a common and consistent strategic lead is available. ASLPSP does however perform a sterling service in supporting operational issues facing its members in areas such as copyright protection and training.
- Several larger UK-based learned societies were visited to get their views on STEM publishing developments. These included directors at Institute of Chemical Engineers/Thomas Telford, Institute of Mechanical Engineering, Society of Endocrinology, Institute of Directors and the Royal College of Nursing. There was little enthusiasm for investigating, by means of questionnaires and interviews, the information habits and needs of their members. Their claim was that these learned societies 'knew their market'. This, however, is not the issue – the concern is the strategic aspects of the STEM publishing process, and in particular its outreach to individual knowledge workers. Little future-focused market research of a purist nature is being undertaken by such societies. They restrict themselves to the current business model. Without an understanding of, and adaptation to, newer more relevant business models publishers face being side-lined by new participants in the information process.
- Both the ICE/Thomas Telford and the Institute of Engineering and Technology felt they knew their markets; the Institute of Mechanical Engineering was reducing its involvement in publishing (selling off its publishing assets). In part this lack of commitment was reinforced by

management changes which were taking place in this sector, with little focus possible on long term strategic issues.

5.14.4. Results from Case Study

The Appendix gives details of two case studies which have been completed as part of this thesis.

The first is a case study of DeepDyve. This is a US Silicon Valley based start-up company which had identified a weakness in the subscription-based business model adopted by STEM publishers. The owners of DeepDyve drew parallels with developments in other industries and established a programme of allowing anyone – affiliated and unaffiliated alike – to 'rent' an article online for a short period of time for which they would pay a minimal amount (99 US cents per article). The articles would be identified on DeepDyve's catalogue and upon payment the individual would be able to read the article on the screen but not print it out (see Intermediary Initiated Business Models in chapter 6.2.3.2)

The case study exposes not only some of the protectionism surrounding STEM publishing but also the difficulties innovative companies outside the traditional structure of STEM face in breaking into this sector.

Personal interviews with the owner of DeepDyve (William Park) and the company's advisor on strategic issues (Joseph Esposito) formed the basis of the case study. The interview was semi-structured, approached with a detailed list of questions which were amended during the course of the interview as new ideas and directions emerged (see Appendix 3.1).

The second case study gives details on the results of the second of the phone interviews on researcher behaviour in the UK (see appendix 3b). This was a small sample of researchers to see whether the macro-level issues many external influences bearing down on STEM publishing – fitted in with researchers' own views and concerns. The phone conversations, lasting on average between 15 and 30 minutes with each of the 20 respondents, was based around ten prepared questions (see questions listed in the Methodology section in chapter 3.2).

RESULTS – 2

STEM INFORMATION INDUSTRY DYSFUNCTIONALITY

The findings described in this chapter refer to STEM publishing as it currently exists. It assesses its sustainability and viability. It then focuses on external developments which will effect a change in its operations. The strategic implications of such changes will then be analysed through the prism of conceptual models developed in other sectors of society but having applicability to the uniqueness of the STEM information sector.

It follows on from the previous chapter where the status of UKW researcher as users was analysed. This chapter goes into the barriers facing researchers as a result of current structure of STEM publishing. Whether this structure is likely to accommodate the growing number of changes which are facing it, or whether it will be remodelled in line with dictates set by emerging disruptive technologies, will be evaluated.

Methodology

The methodology employed is based on an analysis of reports published in a range of media, traditional and alternative, supplemented by contacts and meetings held with industry observers and experts. To complement the desk research a pilot market research component has been added which is described as a Case Study in the Appendix (Appendix 3). These different activities have been brought together to provide a consistent and holistic approach to evaluating STEM dysfunctionality.

The analysis of reports made from meetings with external contacts has been based on discourse analysis, and the interview approach has been semi-structured to allow for creative input from the respondents according to their particular specialisms and experiences.

This chapter has integrated quantitative data to complement the qualitative analysis where such data sources exist - an MMT approach. It has been a feature of this MPhil project, however, that relevant statistical data has been at best spotty and at worst inconsistent and non-comparable from separate sources.

6.1. STEM PUBLISHING SECTOR

6.1.1. Industry facts and figures

The following table is sourced from a variety of external data sources – some reliable and based on public data, some being anecdotal and more indicative. It brings together available data from an industry sector which has been sparing in its provision of information to enable strategic assessments to be made. The numbers given below are an indication on the size of the worldwide STEM publishing system and its component parts.

Table 6.1. Statistics on the size of the scientific communication industry

Funding Scientific Research:

- In 2013, world expenditure on R&D amounted to US$ 1,478 billion, compared with $ 1,132 billion in 2007. Source: Unesco, 2015
- The investment in scientific research is approximately $178 billion. Source CEPA, 2008.

Publishing Revenues:

- The scientific information industry worldwide - books, journals and databases – generated revenues estimated at $23.5 billion in 2011 and $25 billion in 2013 (source: Outsell, 2011; Outsell, 2013) or approximately 1.5% of global R&D expenditure.
- The major part of the scientific information industry was in user time in searching and accessing ($16.4 billion). $2.0 billion was in library access. $1.9 billion was in unpaid peer review. (Source: CEPA, 2008)
- Scientific and technical revenue growth from 2010 to 2011 was 4.3% (to $12.8 billion), and medical grew 2.0% to $10.7 billion (source: Outsell, 2011)
- Scientific, technical and medical journal revenues alone in 2013 were an estimated $10 billion (Outsell, 2013), or approximately 7% of R&D expenditures. Though only 40% of total STEM revenues, the large and growing revenues from search engines account for journals' market share

- Journal publishing revenues in the UK come from library subscriptions at academic institutions (68% to 75% of total) and corporate subscriptions (15% to 17%). This amounted to £112 million from universities and £75 million from all other sources (RIN, 2012)
- Charges levied by publishers to enable authors' articles to be read by all - Gold and Hybrid open access - and not just subscribers to journals – are approximately $172 million (Bjork, 2012a) or 1.8% of journal subscriptions. APC charges vary from $2.5k to $3.4k per accepted article.
- One publisher which has switched from a journal subscription to a Gold open access business model - Hindawi, based in Cairo, Egypt - allegedly had a surplus of $3.3 million on revenues of $6.3 million in 2012 (showing that new business models can be as lucrative as traditional models under certain circumstances).
- The commercial scientific journal publishing industry is dominated by five key players. These include Elsevier which publishes over 2,200 journal titles, and Springer Nature with a similar number. Wiley-Blackwell, Taylor & Francis and Sage are also key players. These are commercial companies which have conflicting missions in meeting shareholder expectations as well as satisfying user demand for publications.
- There are many learned societies which balance their activities in support of education and training programmes for their members whilst also maintaining commercial viability from publishing activities. There are 315 members from 39 countries in the UK-based Association of Learned and Professional Society Publishers (ALPSP), but this is only a small part of learned society publishers worldwide (see ALPSP web site, www.alpsp.org).
- The UK-based publishing industry occupies a major position within global scientific publishing, and generates approximately £800 million of annual export revenues. However, both the USA and the Netherlands are also prominent centres for commercial scientific publishing.
- In broad terms, 52% of global STEM revenues come from the USA, 32% from Europe/Middle East, 12% from Asia/Pacific and 4% from the rest of the world (Ware, 2012a)
- The full cost of publishing a journal article is estimated at £3,000.

Users:

- There are 7.8 million researchers worldwide. Since 2007, the number of researchers has risen by 21% (source: Unesco, 2015)
- OECD has reported 8.4 million researchers (or 6.3 million fulltime equivalent) for 2011. This is mainly for OECD countries but includes a few key non-OECD countries (China and Russia).
- The following table gives the global distribution of these researchers (in '000s)

Region	*2007*	*2013*
World	6,400.9	7,758.9
United States	1,133.6	1,265.1
Europe	2,125.6	2,408.1
Asia	2,498.1	3,318.9
UK	252.7	259.3

(source: Unesco, 2015)

- The *Economist* (19/10/2013) puts the number of researchers at 6-7 million worldwide (Economist, 2013).

- Academia.edu, a new information service, estimated the number of researchers at 17 million (though this figure includes postgraduate students)
- Ware (2012a) puts the number of users at between 6.5 and 9 million worldwide
- The EU remains the world leader for the number of researchers, with a 22.2% share. Since 2011, China (19.1%) has overtaken the USA (16.7%). Japan's world share has shrunk from 10.7% (2007) to 8.5% (2013) and the Russian Federation's share from 7.3% to 5.7%. (Unesco, 2015)
- Approximately 30 million worldwide are readers of science-related literature
- There are 110,000 people employed in the STEM industry globally (40% in the EU) with a further 20-30,000 directly supporting STEM (source Ware, 2015)
- There were 132 million tertiary level students worldwide in 2004 (Weller, 2011)
- There are 4,500+ research based institutions in 180 different countries.
- 9,227 universities are listed in 204 countries (168 universities in the UK alone)
- The National Science Foundation (NSF, 2014) estimates science and engineering workforce in the US alone as being between 5 million and 19 million in 2010.
- NSF estimates 5.4 million college graduates employed in science and engineering occupations in the US. This includes 2.4 million in computers/mathematical sciences; 1.6 million in engineering; in the life sciences 597,000; physical sciences 320,000 (NSF, 2014).
- Scientists and engineers with S&E doctorates were split 46% in business sector and 45% education in the USA (NSF, 2014)
- Small companies are important employers of US S&E graduates – companies with fewer than 100 employees employ 37% of graduates.
- Unemployment rates for those in S&E occupations are lower than those for the overall US labour force – 4.3% in S/E compared with 9.0% in US overall in 2010 (NSF, 2014)
- Between 1960 and 2011 the number of workers in S&E occupations grew at 3.3% per annum, compared with 1.5% per annum for the overall US workforce (NSF, 2014)
- 20% of researchers are repeat authors of journal articles (Ware, 2015).
- There were about 2,500 million article downloads from publisher web sites each year (plus an additional 400 million from other web sites) (ICSTI, 2011)
- The universe of 'knowledge workers' is approximately 500 million (Microsoft, 2010)
- Academia.edu has 5 million scientists as users of its services
- 30 million article citations are made

Standing out from the above data is the large range in estimates – reliability and consistency in such data sources is missing. In this respect the STEM publishing industry differs from many other sophisticated industry sectors where sharing of market and other non-confidential data occurs to the advantage of all participating companies. There is no independent collaborative global agency serving all types of STEM publishers (the International Association of STM Publishers notwithstanding).

However, the indications are that there is a core of 7-8 million researchers worldwide, but with concentric rings surrounding these of postgraduates (10 million), R&D workers (50 million) and knowledge workers generally (over 400 million). There are 260,00 R&D staff in the UK (Unesco, 2015).

Output:

- Globally 3 million STEM manuscripts are submitted each year to scientific journal publishers (ICSTI, 2011)
- Only 1.85 million articles were actually published in 2012 (the rest were rejected in their current form, but are frequently and subsequently recycled into other journals)
- Article output and journal titles are increasing by at least 3.5% to 4% per annum (in line with research activity) (Mabe & Amin, 2001; Mabe, 2003)
- 28,135 scientific journals (refereed, scientific, still active) were being published in 2014. A further 6,450 were non-English. (though they are available in 55,311 different formats) (Ulrichs, 2014)
- Approximately 500 new STEM journals are launched each year
- The number of STEM publishers is estimated at between 5,000 and 10,000. There is a long tail of single journal publishers who may not regard themselves as primarily being publishers.
- 650 publishers, responsible for 11,350 journals (or 40% of total), are members of main publisher trade associations (Ware, 2015)
- Of these, 480 publishers (73%) and 2,334 journals (20%) were not-for-profit publishers (Ware, 2015)
- 40 million articles are available digitally, back to the early 1800s.
- 2.5 billion document downloads from publisher web sites annually (Ware, 2015)

Overall, there are 1.85 million journal articles published each year in 28,000 journals. The core commercial journal publishers are approximately 5-10, though these represent a small proportion of the global journal publishing industry of up to 10,000 companies. There is a long tail of small, esoteric publishers.

Editorial:

- 5,000 new editors are recruited by publishers each year, to add to the current total of 125,000 editors (ICSTI, 2011)
- There are 350,000 editorial board members
- Over 5 million referees are included in the quality control system
- 30 million+ author/publisher communications take place each year
- 230,000 open source projects are available

STEM journal publishing sector involves management of a large network of editors, referees and authors – a crucial administrative function performed by traditional publishers. The costs of maintaining this network is supported by subscriptions and document delivery charges.

Intermediaries:

- Search services such as Google and Yahoo are expanding more rapidly than the industry as a whole.
- Google alone accounted for 87 billion online search queries in 2009 out of global total of 131 billion
- In 2009 Wikipedia accounted for 55.6 million online searches
- Traditional intermediaries in the academic sector - journal subscription agencies and booksellers - have faced a torrid time over the past two decades, and many

have eased operations (the most recent example being Swets which declared bankruptcy in September 2014). (*Against the Grain*, 2014).

- Disintermediation by publishers had become a commercial strategy adopted by a few dominant players

Sources: Based in part on report at ICSTI Summer Conference, Beijing, by Hugo Zhang (Managing Director of Elsevier Science and Technology, China – Zang, 2012). Ulrichs list of titles. 'The STM Report', Ware and Mabe, STM Association, 2012.

In 2013 Elsevier undertook a comparator survey among key countries which provided the following as a summary of UK conditions:

UK Researchers

262,303 in 2011

* Increased at 0.9% pa (2007-2011)
* Ranked 5th among leading comparator countries in 2011
* Represents 3.9% of global total (2011)

UK Higher Education [based] Researchers

163,505 in 2011

* Increased at 2.1% pa (2008-2012)
* Represents 62.3% of UK Researchers (2011)

UK PhD Graduates

20,076 in 2011

* Increased at 3.4% pa (2007-2011)
* Ranks 4th amongst comparator countries (2011)
* Represents 62.3% of UK Researchers (2011)

UK Research Mobility

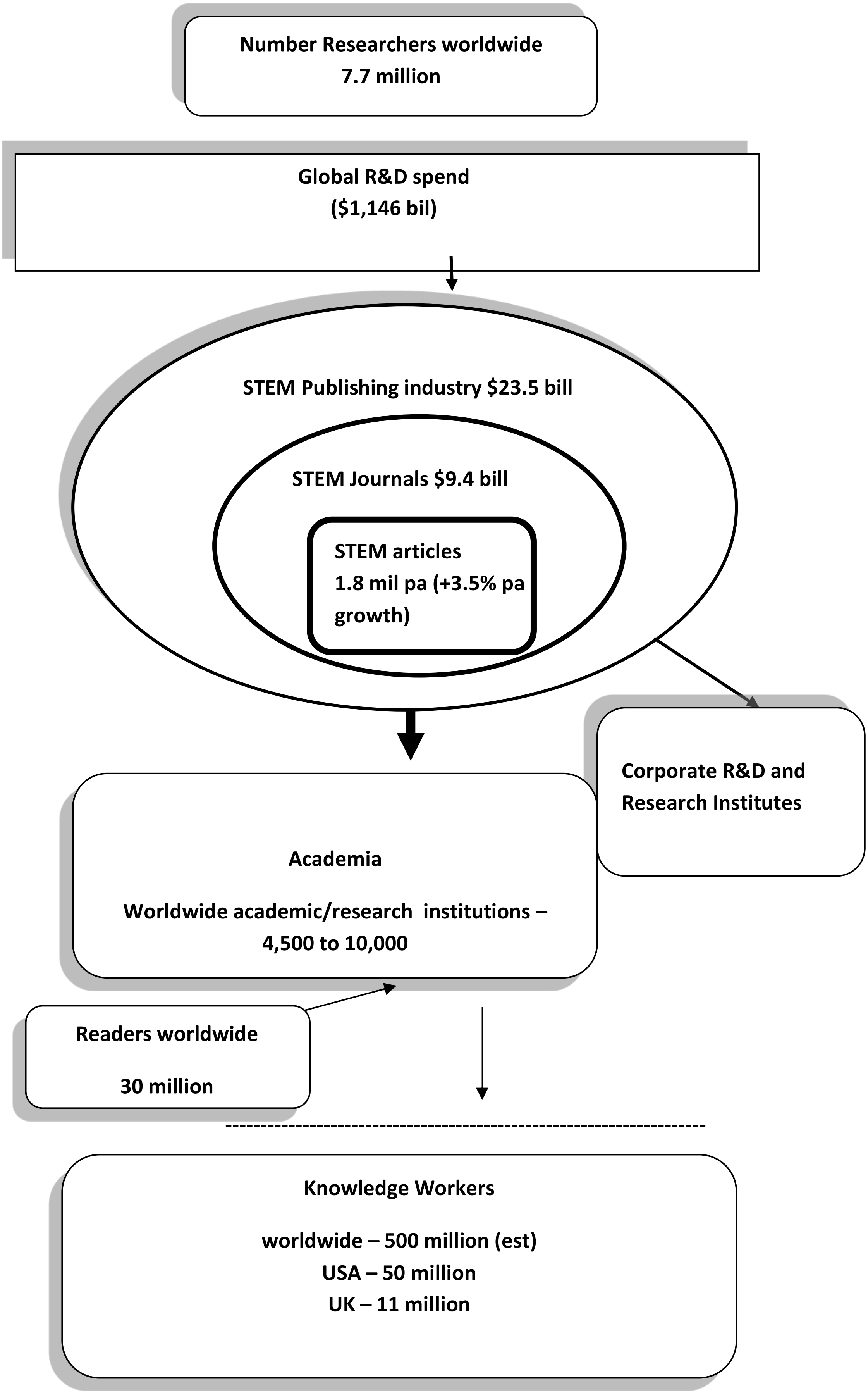
71.6% of researchers were internationally mobile (1996-2012)

* Ranks 2nd among comparator countries
* 3.3% net total outflow of active researchers

(Source: Elsevier, 2013)

In summary, the following chart shows how the various elements of the STEM process are related to each other.

Graph 6.1. The STEM Publishing Industry in Context



Source: Author of thesis

6.1.2. Strengths of STEM sector

As a service industry in support of the creation and dissemination of research results, the scientific communications sector has many advantages. It is a solid sector, with an established history of stability among key players. There is a well-developed editorial and marketing infrastructure in place provided by STEM publishers. They manage a large global network of contributors to the STEM information dissemination process. It has the support of the main body of authors and researchers worldwide on the basis that that the system ensures that quality is maintained. There are powerful brands in place in which authors and users place their trust. A network of reputable in some cases physically spectacular and imposing libraries act as custodians of STEM's archive.

This translates into a conservatism which acts a brake on dramatic changes being made to traditional ways of operation.

Nevertheless, STEM is faced with a confusing cocktail of new threats. Whilst its players focus in general on immediate actions to improve operational efficiencies they neglect tackling strategic challenges. "The debate between quick scientific gains and long-term public investment in basic and high-risk research to enlarge the scope of scientific discoveries has never been so relevant" (Unesco Science Report, 2015).

This has led to the outcry in formal and informal literature that stakeholders in the dissemination of STEM output have become dysfunctional (see section 6.3). Underpinning the current STEM publishing system is a business model which was developed under a previous (print-based) paradigm. This business model comes in different forms from different agencies in the STEM structure. These are summarised in the next section.

6.2. BUSINESS MODELS

The business model which operates for STEM may no longer be viable if any of the following conditions exist (Dawson et al, 2016)

- Customers have to cross-subsidise other customers
- Customers have to buy the whole thing for one bit they want
- Customers cannot get what they want where and when they want it
- Customers get a user experience that does not match global best practice

At least two of the above conditions apply, potentially three. In addition, the main STEM business models do not take into account external developments impinging on STEM and as such are vulnerable. (See: "The economic essentials of digital want IT strategy", McKinsey Quarterly, March 2016).

However, there are a number of business models which are in evidence from different sectors of the STM industry. The following analyses the models not only those from STEM publishers but also those employed by librarians, intermediaries and researchers.

Methodology

The methodology employed was primarily desk research and an analysis of STEM trade literature to identify the variety of business models implemented by the main STEM stakeholders. Discussions with representatives from the industry also included a discourse analysis of their attitudes towards the appropriateness of current business model in their areas of expertise and experience.

There are different corporate missions behind each of the stakeholders which determine the extent to which profit maximisation is sought. These range from the high profits margins achieved by large commercial STEM publishers to the more socially-focused projects initiated by researchers whose aim is to develop effective informal communication channels rather than pursue profits.

It appears the common factor from the main industry players is that they are not proactive in extending outreach of publications to non-affiliated professional or related audiences.

6.2.1. Publisher Initiated

6.2.1.1. Serial subscription and site licensing model (including e-document downloads)

* The business model for publication of research articles and conference proceedings has evolved over three and a half centuries. The research journal has become the main delivery vehicle for updated reporting of scientific results.
* Subscriptions (income from sales of journal titles) and licences (contracts between individual publishers and libraries) constitute the main formula used by publishers in support of their operations.
* These subscriptions and licence business models depend for their success on the health of the institutional research library budget.
* The subscription model faces a budgetary challenge as the gap between scientific output (and prices) and library budgets grows (see section 6.3.1).
* Nevertheless subscription/licences still remain the base business model from which several large commercial publishers generate healthy profit margins (in some cases 30-40% of net revenues)
* Built on the subscription/licensing system has been so-called ‘big deals’ which offer libraries much more of a publisher’s output for a small additional charge.
* Included within a subscription or licence are details of who is entitled to download electronic versions of articles from the licensed package. This is restricted to the main patrons of a research library only, and not to knowledge workers generally.
* As such, subscription/licences enforce a padlock on research literature, open only to those few organisations which have the funds to unlock access.

6.2.1.2. Online individual document purchase (from the publisher site)

* Individuals not entitled to access online journals can purchase articles through payment of an article charge set by each publisher and accessed directly from the publisher’s web site.

* Publishers are hesitant in supporting sales of individual articles as it may cannibalise the subscription business model, though there is insufficient evidence that this is the case.
* There is often a high price deterrent set by publishers which detracts from more sales of individual articles – individual article prices delivered electronically are often in excess of $30.
* Publishers face higher internal administrative costs associated with collecting large numbers of small payments for individual article sales, which places stress on their existing institutional-focused operational structures.
* A price reduction could help determine the elasticity of demand, leading to optimal business strategies being developed catering for the long tail of knowledge worker demand (see section 6.4.1.2).
* DeepDyve (see Case Study in Appendix 3.1) has disclosed the following document ordering activity on an unnamed but representative publisher's STEM platform.

Table 6.2. Article purchases from a publisher web site

Traffic per year:	40 million visitors
Non-institutional traffic per year:	20 million visitors
Document delivery sales per year:	$1 million
Average article price:	$25
Number of docdel transactions:	40,000
Docdel conversion rate of non-institutional site visitors	0.2% (40,000 transactions/20 million visitors)

(Source: Correspondence with William Park, CEO, DeepDyve, September 2010)

The Chief Executive Officer of DeepDyve, William Park, also claimed that the estimated number of visitors to the DeepDyve site that were non-institutional visitors ranged from 35-60% (Park, 2009). Many of these could be counted as UKWs. A more acceptable pricing strategy could have transformed a proportion of these latent non-institutional visitors into article purchasers.

6.2.2. Library Initiated

6.2.2.1. Institutional Repositories (IRs)

* Research institutions have established digital repositories, often maintained by the library, which include all research material published by in-house research staff (Crow, 2002).
* Items deposited in the IRs can usually (subject in some cases to a time moratorium) be accessed by anyone – affiliated as well as unaffiliated – for free
* Researchers often find it time-consuming to deposit their research results in their local IR and see no personal value from doing so
* To overcome current reluctance to make such deposits, researchers are often mandated to submit their outputs to preferred institutional repositories
* Institutions gain value from exposing to the world the quality of the research effort being undertaken by their researchers - this is a reputational rather than financial issue
* Potential conflict with publishers over the impact of IRs on articles delivered from publishers was explored in a EU-funded PEER research project with no conclusive resolution (Wallace, 2011)

6.2.2.2. Document delivery

* Printed copies of articles can be purchased by individuals through specialised document delivery centres. National scientific agencies have been crucial in establishing such operations, notably the British Library Document Supply Centre (Appleyard, 20
10), but also in France, Canada, Korea. Private companies have also been established in the past to deliver documents on demand.
* E-delivery of such documents is possible with the agreement of the publisher (with charges including processing costs and royalties, as against processing costs alone for direct supply by the publisher)
* However, national and international formal document delivery traffic has been declining rapidly during the past decade (by 75% in the case of BLDSC)
* Document delivery centres perform a valuable service by creating a comprehensive catalogue of all electronic articles (such as BL's ETOC) and establishing a centralised one-stop purchasing centre (thereby avoiding

searching across thousands of publishers' web based silos)

6.2.2.3. Interlibrary Loans

* Sharing published resources between research libraries is mainly focused on loans of physical books rather than delivery of research articles
* The ILL process imposes a significant cost burden on large, comprehensive research libraries in supporting many libraries having smaller collection development budgets
* This represents more of a fall-back for libraries if they cannot serve their local patrons from any other source

6.2.2.4. Walk-in access

* Walk-in access allows an individual open access to a library's physical/printed collection. (Different rules apply for walk-in access to digitally held material).
* Walk-in procedures for e-articles are currently being negotiated, but remain subject to licensing terms agreed with the publishers.
* There can be a geographical barrier to accessing such printed collections by external researchers – this involves the physical distance to/from home or office.

6.2.2.5. Alumni

* Several projects involve experimentation with delivery of publications to the university's alumni without authentication barriers being put in place (ProQuest Udini).
* In the past alumni have mainly been excluded from publishers' licences

6.2.2.6. Public library access

* Publishers Licensing Society (PLS) is conducting trials to see whether a sustainable business can be developed whereby public libraries can be brought within nationally negotiated licences (Faulder, 2015).
* Similarly, Jisc Collections is conducting trial to see whether SMEs can be included within national academic licences.

6.2.2.7. National Licensing models

* Problems of organising a feasible structure, and getting buy-in from a representative set of publishers and libraries, has prevented national licenses being established in the UK so far. However, Scotland has a scheme in place.
* Complex issues such as cross institutional use, home access, etc., would all be resolved through a broad licence model.
* National licences require central coordination, and central funding – a new collaborative business model – which would only operate in select areas and with commitment from all sectors

Though there is some movement in redefining the scope of licences, these are long and protracted discussions with publishers who need to protect their commercial interest by not allowing access rights to be given away too freely.

There are indications, however, that by enabling public libraries (or enabling special research areas such as in physics with SCOAP^3) to include non-subscribing, non-traditional researchers to be included within the new licences, that libraries are pushing the boundaries. UKWs could ultimately become beneficiaries in these experiments.

6.2.3. Intermediary Initiated

6.2.3.1. Subject based repositories

* Related to the above, there are a few subject areas where preprints of articles are deposited and made available for free. These include biomedicine (PubMed), physics (arXiv), social sciences (SSOAR).
* Funding in these instances comes from a variety of sources
* There are several subject-based site licensing initiatives. SOAP^3 is one such scheme which includes libraries and publishers agreeing to worldwide free access to a selection of physics journals. (Anderson I, 2008)

6.2.3.2. Pay-per-view (PPV)

* Pay-per-view (PPV) has the potential to reach beyond the library into wider knowledge worker sectors though the barrier is often the high price set by publishers for the delivery of individual articles through intermediaries
* There are experiments being undertaken, with DeepDyve being an example, where articles are ‘rented’ rather than ‘bought’.
* A key feature of these PPV initiatives is that they could address a new market sector for scientific publications if acceptable pricing issues were addressed

6.2.3.3. Premium subscription services (Freemium)

* These usually focus on specific disciplines with a broader range of information services being offered – not just journal articles. They include a package of services
* The publishing industry needs to take on board the openness, collaborative aspects of this business model and separate some ‘free’ aspects from premium (chargeable) services.

Intermediaries have been struggling to maintain a niche for themselves within the printed business model for STEM - they have suffered disintermediation for decades. They have been squeezed as both publishers and libraries vie to promote their own commercial interests or protect their budgets. However, this does not preclude intermediaries developing new niches with new business models in future particularly in partnership with the research community.

6.2.4. Author/End User Initiated

6.2.4.1. Social networking and social media

* Perfect Storm forces are attracting greater adoption of Web 2 services (see sections 5.9 and 6.4)
* Social networking may be the process whereby scientific communication is interfaced with the needs of knowledge workers in future (see 5.12).

6.2.5. Mixed Initiatives

6.2.5.1. Open Access

* Open access allows the end user ‘free at the point of usage’ access to published articles
* There are a number of open access systems being implemented for STEM material - Green, Gold, Grey or Hybrid routes (Guedon, 2004; Harnad, 1994).
* Green (author-self archiving) model operates within Institutional Repository setting, enforced in some cases by mandates issued by funding agencies to ensure deposit of the research output (see above under Library Initiated)
* Gold (author pays) requires an author (or their affiliation) to pay a fee to the publisher to have their articles published
* Hybrid involves a journal offering a subscription model within which Gold articles can be included (paid for by the author) and accessed for free. However it opens itself to ‘double dipping’ with publishers charging twice for access to the same article
* Few of the above are commercially viable or substantially entrenched as yet.
* Open Access has the virtue of linking in with broader society developments – the Open Information Systems within IT generally.

With the above business models there is growing support for more openness. This is only balanced in the research sector by a traditional conservatism and reliance on the established reward system.

Should the reward system affecting researchers be changed so that a formal published article in a respected refereed international journal would no longer carry the weight it has in the past with funding agencies, this would do much to create a swing to open access publishing at the expense of some (but not all) subscription-based publishing.

6.3. A DYSFUNCTIONAL STEM

6.3.1. Tensions within the existing system

Scientific journal publishers emerged over centuries to provide formal publications of research output in a structured and quality controlled way, and research libraries became agencies which were allocated funds with which to purchase published scientific research. This dualism became the main operational infrastructure enabling a smooth transfer of high level knowledge within the scientific community. However, in so doing it has operated under two conflicting business cultures.

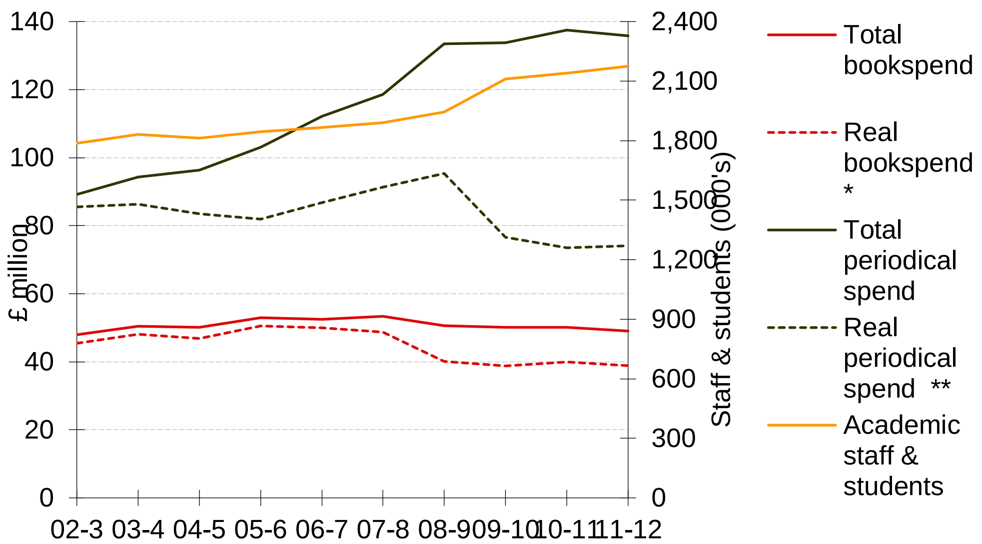
- On the one hand, the published scientific output, or '*Supply'*, continues to grow. Leading driver for the expansion in article supply is competition between researchers, and their attempts to advance their careers through publishing more and better articles. It can lead to unfortunate consequences such as 'salami publishing' (splitting research results into many separate publications), duplication of research outputs, plagiarism, etc. These all increase the supply of available publications, but essentially it is stimulated by competition between researchers for research funds.

  Within a society which exploits the results of research activity in order to improve economic performance and international competitiveness, increases in R&D funds have been made available. As reported in the Unesco Science Report in 2015, (Unesco, 2015), most countries, regardless of their level of income, now see research and innovation as key to fostering sustainable economic growth and furthering development. The combination of micro level competitiveness (at the personal level) and macro level support for research (at the national level) are powerful stimuli for continued growth in research output at rates of over 3.5% pa overall (Mabe, 2001; Ware, 2012b).

- *'Demand'* is driven by an unrelated set of issues. Research publications are purchased through the library's collection development budget. As science continues to grow (Mabe, 2001; 2003), as student levels worldwide increase at about 6% per annum (Unesco, 2010), and as technology offers an ever widening range of applications arising from research, the increase in a research library budget would need to be comparable to cope with demand at a rate in excess of 5-10% per annum. This has not been achieved. At best library budgets have remained static in real terms in recent decades - at worst their buying power have diminished despite serial collection budgets being prioritised at the expense of other library activities.

There has been an ongoing increase in unit pricing of STEM publications over the years despite the above imbalanced supply and demand equation. The rate of price explosion can be seen from the following graph of book and serial costs in the UK from 2002 to 2012 as collected by the Library and Information Statistics Unit (LISU, 2012) based at Loughborough University.

Graph 6.2. Total expenditure Books and Periodicals



Source: LISU, Loughborough University, UK

The above graph shows the decline in real spend on books and journals in the UK university sector despite an upward growth in academic staff and students – the people being served by the libraries.

The percentage growth in periodical prices by discipline in recent years has also been collated by LISU, and illustrates that price increases by the main publishers serving academic libraries have risen between 5% and almost 8% per annum for the main STEM journals.

Table 6.3. Average growth in periodical prices in the UK by subject area

Average prices	2013	% increase 13 over 12	2012	% increase 12 over 11	2011
Social sciences	£594.96	5.7	£565.51	4.4	£520.62
Science	£1,672.37	4.9	£1,560.87	5.5	£1,429.52
Medicine	£980.40	6.9	£1,035.86	6.2	£819.53
Technology	£979.28	5.3	£1,112.42	4.6	£867.22
Humanities	£230.10	7.7	£212.30	5.0	£199.14
General	£449.37	6.9	£270.93	3.6	£281.73
No of Titles (1)	27,117		24,470		24,343
Average all subjects (2)					
U.K.	£817.75	5.7	£792.98	5.1	£686.29
USA	$1,188.63	6.5	$1,106.06	4.5	$1,023.79
EURO Region	€ 884.32	4.7	€ 909.77	5.5	€ 828.76

Source: LISU, Loughborough University, U.K.

It is apparent that there has been a sizeable commitment to the purchase of serials in the hard or natural sciences by research libraries in the UK, and that this has been driven to a large extent by the increase in prices. This is in contrast to their commitment to purchasing monographs which has declined relatively over the years.

The main problem is that research libraries' funding sources is divorced from the production and output of research results. As such, research libraries have difficulty maintaining a credible collection in an era of 'digital information overload' (CEPA, 2008; CEPA & Ware, 2011).

6.3.2. A further Paradox in STEM publishing

Traditional scientific publishing displays distinctive characteristics, different from other publishing areas. There are a further three distinct processes.

- On one hand there is the 'closed circle' of scholarship whereby authors are also readers, and as authors they seek recognition and esteem for their work rather than expecting a financial return from publication. They give up rights over their published results to third parties (publishers) in order to have their research efforts made available to their peers throughout the world. Achieving worldwide recognition was the main recompense they sought, as this often became the source of additional funded research, academic tenure, visibility and/or personal career advancement. An Ithica S&R survey involving almost 7,000 UK academics in 2015 identified that "since 2012 there has been a substantial increase in the share of academics that shape their research outputs and publication choices to match the criteria they perceive for success in tenure and promotion processes" (Ithica, 2016). The problem is that the success criteria are centred around so-called Journal Impact Factors (JIF) which are increasingly being criticised for being at best an inelegant measurement, at worst destructive to science (Bohannon, 2016).

  Overall, no money changes hands for this service for allegedly indicating journal quality – it is 'a gift economy'.

- Parallel to this is payment for the quality control, production and dissemination of research results. This is handled by research funding agencies, publishers, subscription agents and institutional libraries. The latter are provided with the funds with which to buy the output from the publishers.

  Money is at the heart of this process. It is a 'transactional economy'.

- It is also the case that, in the UK, 54% of the research undertaken is funded by industry. In the USA it is approximately 66%, with over 70% of the research performed in industry (NSF, 2012). Despite this, a majority of research articles are written by academic authors.

The proposition is that there is migration from a transactional to a gift economy as the sector moves from elitism towards openness, transparency and digitisation. This has implications on the market structure for STEM publications in future, making the current business model unsustainable, particularly during the period of migration (see 'valley of death' in section 5.9.4.4). It also impacts on whether UKWs can be brought into the mainstream research system.

6.3.3. Antagonism and mutual recriminations

Meanwhile, the current STEM system is characterised by increasing antagonism. One contributor to the debate (Wikoff, 2015) claimed:

> "I would love to see publishers, vendors, authors, and librarians sit down and talk straight about what can be done to reach that shared goal because right now, it feels like we are on the edge of a freefall where academic publishing is increasingly not sustainable, and all the parties are just more entrenched than ever. It's very, very hard to get people to set that stuff aside and work together towards making it all work. I don't know if it can be done, but we are not getting there the way we've been operating up to now -- in a competitive, antagonist way".

In the USA, Harvard University has thrown its weight behind complaints against STEM publishers. Its concerns were expressed in a letter sent in April 2012 by Harvard's Faculty Advisory Council to the faculty alleging a crisis with acquiring scientific journals. The letter – entitled 'Major Periodical Subscriptions Cannot Be Sustained' - reported an "untenable situation facing the Harvard Library" in which "many large journal publishers have made the scientific communication environment fiscally unsustainable and academically restrictive." A few scientific journals, it said, cost upward of $40,000 a year each. "Prices for online content from two providers have increased by about 145% over the past six years, which far exceeds not only the consumer price index, but also the higher education and the library price indices". It concluded that "Major periodical subscriptions, especially to electronic journals published by historically key providers, cannot be sustained." (Harvard University, 2012).

Other complaints come from the research community. For example, in 2013, four academics from the University of Leicester's School of Management, tried to bring the debate about steadily increasing prices of publications into a journal published by Taylor and Francis, only to have the article censored by the publisher. This led to the editorial board threatening to resign unless the article was reinstated. The debate was to appear in the journal *Prometheus: Critical Studies in Innovation*. Its title – 'Publisher, be damned! from price gouging to the open road' – included comments which criticised the excessive profits made by commercial publishers. This epitomises the different positions which authors and publishers are taking over STEM business issues.

6.3.4. 'Frustration Gap'

The imbalance between supply and demand forces can be quantified by looking at the expenditure by a country in its national research and development budget as compared with the expenditure on research libraries during the same period. For the United States such a comparison is illustrated below. The growing gap between the supply and demand systems becomes evident.

Graph 6.3. US Academic R&D Expenditure and ARL Library Budgets, 1976-2003

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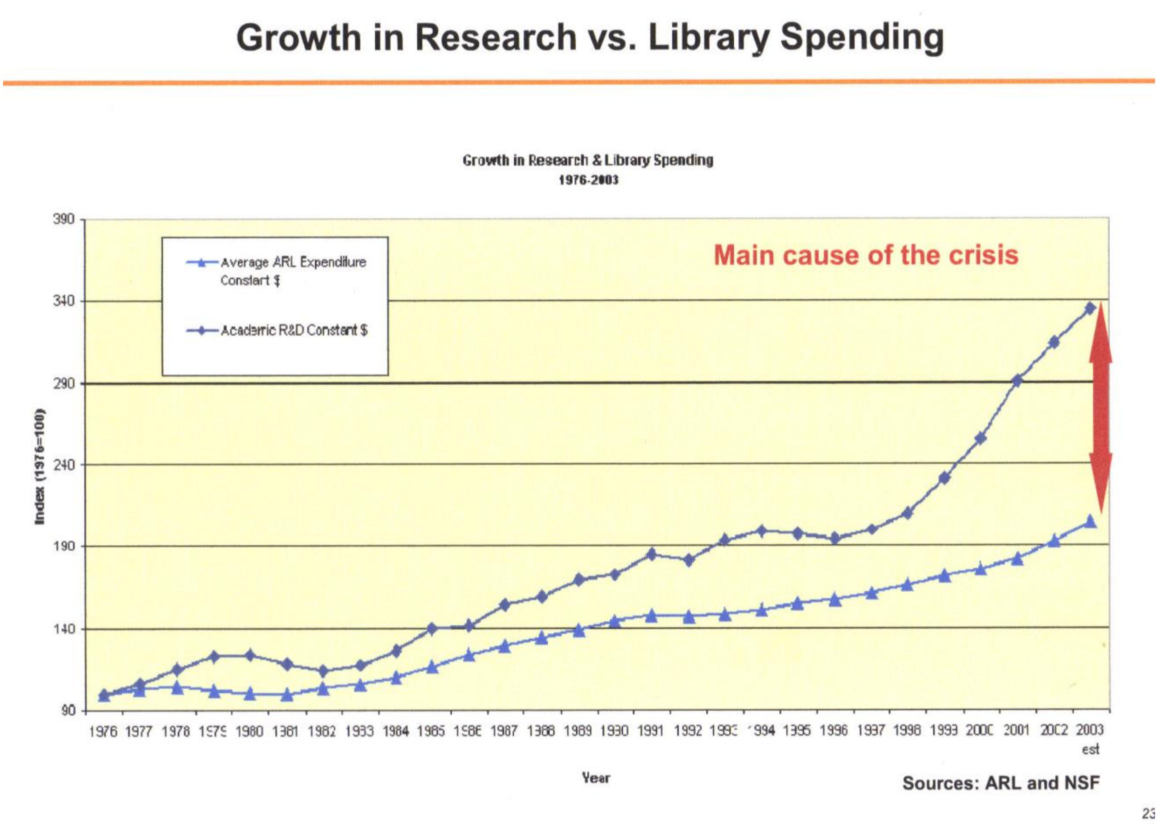
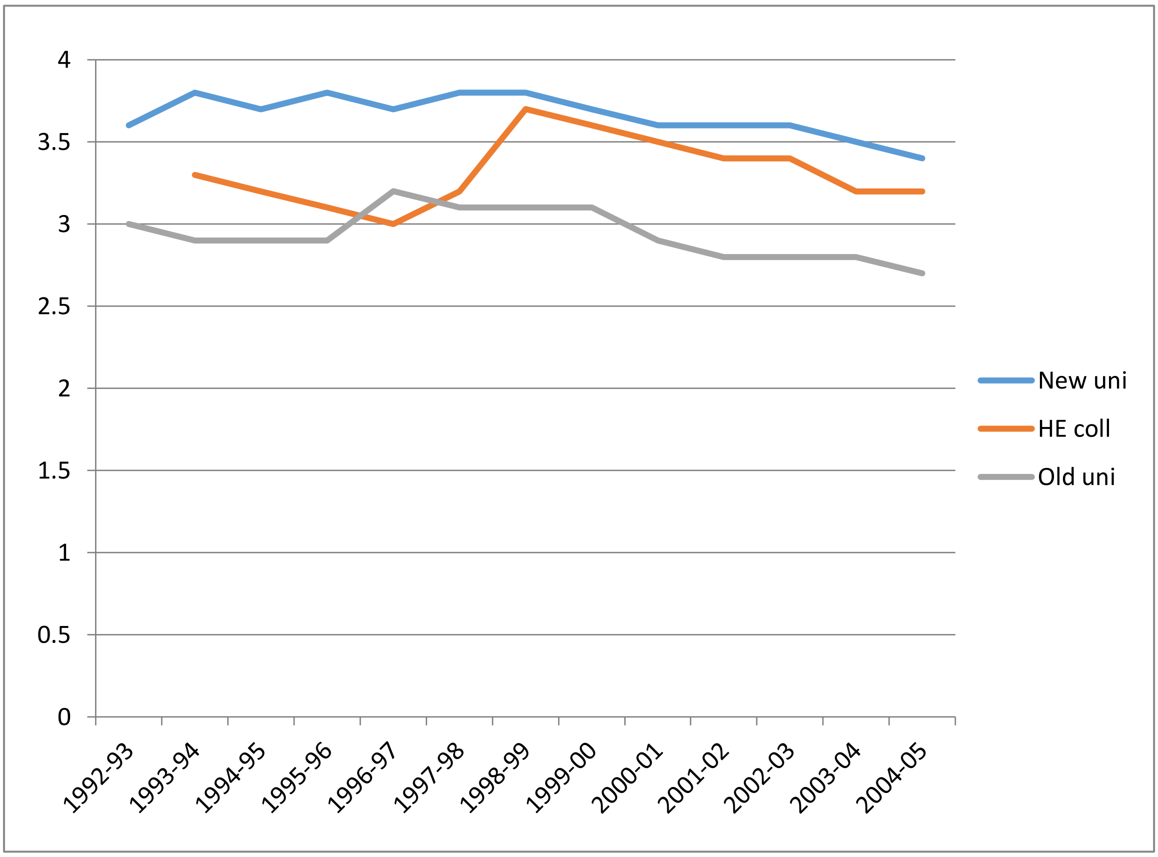


The divergence of the two lines – supply of and effective demand for scientific material – has been referred to as the 'frustration gap'.

A further metric showing how librarians have difficulty coping with the growth in publishing output is the falling share of the library budget, in comparison with the overall institutional budget. Between 1994 and 1999 the percentage share of the library budget compared with its institutional budget of leading higher education (university) institutions in the UK was approximately 3.8%. Since then there has been a gradual decline each year down to 3.4% in 2005. As far as Research Libraries UK (RLUK) members are concerned, the reduction has been equally marked, having fallen from 2.09% in 2007 to 1.82% in 2009 (source: SCONUL Annual Returns).

The following figures illustrate the decline in the library share of the main types of higher education establishments in the U.K.

Graph 6.4. Percentage of UK institutional budget spent on their research libraries



Source: SCONUL, 2006

In the USA there has been a similar downward trend, with library expenditure as a percentage of institutional spending falling from 3.83% in 1974 to 1.8% in 2011 (source: Association of Research Libraries, 2008 and Davis, 2014).

Whether these reductions reflect increased competition for the institutional budget, or whether it indicates the declining relevance attached to the research library and its role within the institution, is difficult to determine. But there is concern that libraries cannot use the same financial metrics to advance their financial case as can other departments within the same institution (CIBER, 2009). Payback which comes from an expansion in the library is less easy to demonstrate, whereas other departments can point to an increase in student numbers or research grants to support their claims. Libraries are an intangible infrastructural support service – in many cases desirable rather than seen as an absolute necessity when it comes to the institution's annual budgeting cycle.

6.3.5. 'Serials Crisis'

The confluence of the above has led to the 'serials crisis' which faces the community. Governments in the US, UK, Australia, Canada, and the European Commission have all expressed concern about the serials crisis within their respective national science economies.

The crisis is a financial one. Journal subscription prices are rising at a faster rate than most other indices. But the price rises by publishers are neither consistent nor universal. Bergstrom and Bergstrom (Bergstrom & Bergstrom, 2004) examined the rates charged by publishers, comparing those of for-profit companies with those of non-profits. The authors concluded that a journal page published by a for-profit publisher is between three and five times more expensive than one published by a not-for-profit publisher. Highly-cited journals are perceived to be of better quality, which allows for-profit publishers to charge even higher prices for such journals (McCabe, 2004; Dewatripont et al., 2006).

Several measures have been taken to reduce the financial pressures on libraries. 'Big Deals', enabling libraries to get more bytes for their buck, have been introduced by larger publishers and publishing consortia. This allows for more journals to be delivered at lower per unit costs providing the library commits to taking more of the publisher's output. It means that the total amount paid to each publisher increases – the extent being determined by how large the publisher's list is and what proportion had already been subscribed to by the institution. Publishers have also offered the ability for end users to buy individual articles on demand from their web site, at what is generally considered by both the library and end user communities to be extremely high prices (see earlier section 6.2.1.2 on Business Models).

Coming to terms with the imbalance between supply and demand is essential for a healthy information service. Unfortunately, an open-minded approach to relating what is perceived as a 'need' with creating an appropriate 'serviceable system' is not being pursued by stakeholders. In particular there are many factors outlined above in creating concern and criticisms about the current state of STEM information. Key among these is the corporate mission which is being pursued by the large commercial publishers.

6.3.6. Investors versus customers

A significant part of scientific journal publishing has become commercially driven, dominated by a handful of international journal publishers with the interests of corporate and private shareholders being just as important to the company as satisfying the needs of users in the research community. Even those organisations which nominally operate under the banner of 'non-profit' (such as learned societies) often pursue commercialism ('surpluses') as intensely as their for-profit competitors.

It is inconceivable that the interests of shareholders seeking optimal financial returns, as against those concerned about the efficacy in the mechanism for supplying a 'public good', can be reconciled given the practices which are currently in place.

Commercial journal publishers need to persuade their owners, investors and the financial sector, that they are acting in their best interests. The financial sector scrutinise company balance sheets to see whether they meet short term commercial expectations and are suitable candidates for investors. Whilst publishers focus on editorial strengths, or global marketing coverage, or new product launches, the City is interested in financial returns, profits, margins and business relationships. It is the financiers who are important in determining where invested funds go, particularly as several of the large publishers are owned by venture capitalists. The latter's main aim is in seeing that their investment in the company achieves payback within a specific period of time. Investment services, such as media equity researchers at Exane BNP Paribas and Bernstein Research, keep a watchful eye on financial reports issued by each commercial journal publisher (Poynder, 2012b).

This means that a scholarly publishing company needs to produce financial figures each year which are strong and healthy. However, users and libraries who currently buy their STEM products become alarmed when such healthy figures go beyond what is judged acceptable, leading to claims against publishers of ‘price gouging’, greed, and creating dysfunctionality (see section 4.1.2).

The following table shows the revenues and operating profits which several of the largest commercial, university press and society publishers declared in their 2013 corporate statements. These figures include revenues from other publishing activities, not just scientific journals, though the latter often exert a heavy and positive influence on their overall returns.

Table 6.4. Revenues and profits from the major STM journal publishers (2013)

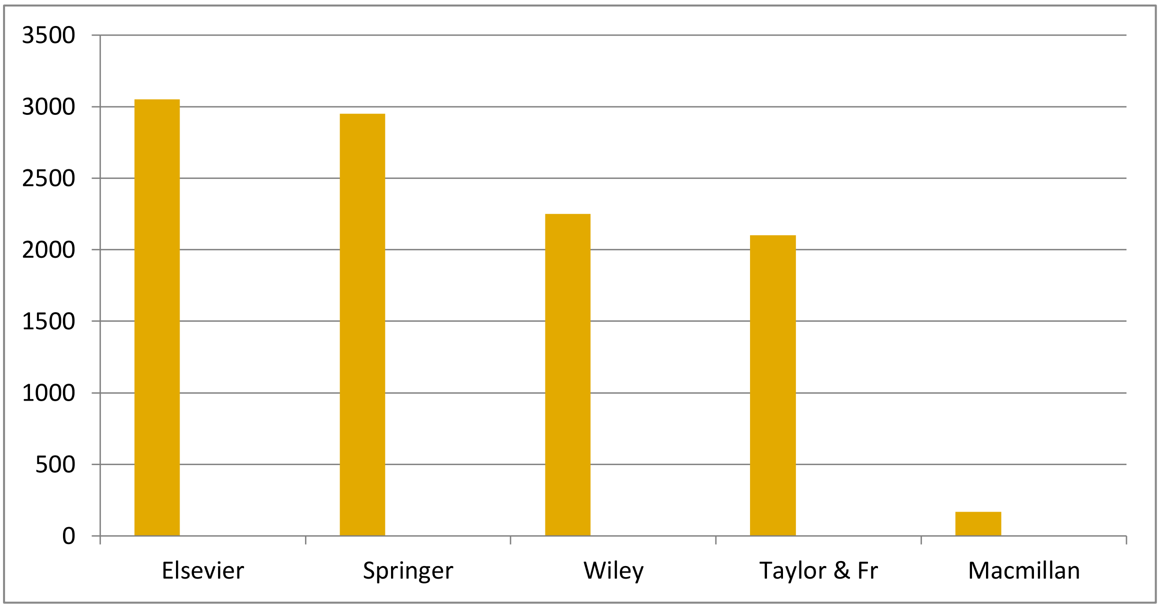
Company	Revenues (in £mil)	Operating Profits (in £mil)	Profitability ratio	Year end
Elsevier	£2,126.00	£826.00	38.85%	December
Wiley	£649.84	£270.89	41.69%	April
Taylor & Francis	£367.10	£130.90	35.66%	December
Oxford University Press	£759.20	£103.40	13.62%	March
Cambridge University Press	£261.70	£8.20	3.13%	April
American Chemical Society	£301.89	£10.18	3.37%	December

Source: Annual published Accounts for each publisher

In 2014 Elsevier Science was targeted as the main villain of the piece. Its almost 40% operating profit margin had in the past been overlooked from public scrutiny possibly because of the small scale of the industry sector. Several publishers, such as Springer S&BM/Nature Publishing Group, Sage and Emerald, do not disclose their financial results due to their being in private hands or are in closed ownership. Nevertheless, the drive for healthy financial returns for these privately held companies also exists. It is apparent from the above figures that commercial journal publishers are making profits way over what could be seen as acceptable in a business environment which relies on a ‘gift economy’ sustained by the public sector.

The following graph shows the numbers of journal titles which the main publishers produced in 2014. These figures should be seen in the context of there being 28,135 STEM journal titles published annually worldwide. It illustrates the degree of concentration within STEM publishing.

Graph 6.5. Number of Journals in Publishers Portfolios



Source: Data from publishers' web sites and media reports

Librarians are concerned about such concentration. As Rick Anderson, associate dean for scholarly resources and collections at the University of Utah in Salt Lake City, suggests "Publishers are fielding more and more submissions and chasing smaller and smaller budgets while also dealing with an increasingly complex scholarly communication environment. Its a very tough position to be in" and "I think more consolidation is inevitable" (Chawla, 2015).

The Office of Fair Trading (UKOFT, 2002) looked at the potential monopoly situation facing the STEM journal market resulting from the merger of two large commercial publishers (Elsevier and Harcourt) and in a statement issued in September 2002 claimed there was evidence that the market for STEM journals was not working well. The complaint was that commercial journal prices were too high in comparison with education and research institutional budgets. However, it was considered then (in 2002) that it would be inappropriate for the Office of Fair Trading to intervene.

There was a spate of merger and acquisition (M&A) activity among commercial publishers in the 1980's and 1990's. Recent mergers included Wiley taking over Blackwell Scientific in late 2012, and Thomson Reuters selling its Science Business to venture capitalist Onex and Baring for $3.5 billion in July 2016. Springer S&BM has been sold recently by one venture capital group to another with a final twist being the announced merger of Springer and Nature in January 2015.

Despite STEM publishing being hailed as inefficient, inequitable and dysfunctional, the traditional journal publishing model still remains the prime information delivery vehicle.

The answer to such dichotomy may be found in the writings of economics laureate Kahneman who suggests that there are other motives besides efficiency in dictating action. Kahneman in "Prospect Theory: An analysis of Decision and Risk" (Kahneman, 1979) suggests that 'losers' always fight harder than 'winners' to protect their interests. This means that it will always be a harder struggle to effect change than it is to preserve the status quo. The publishing industry will preserve its lucrative business rather than take risks in pursuing unknown business paradigms.

The consequence is that there remains market control by a few large commercial and society publishers, and as technology, globalisation and social factors all change, the dominance of a few companies over the current publishing scene may continue. They have the resources to survive market upheaval for longer than their smaller competitors. This dominance does not bode well for UKWs who are not beneficiaries of the business model which large commercial publishers prefer to use.

The groundswell of concerns about the dysfunctional nature of scientific journal publishing from sectors other than publishers has reached significant proportions. It is not only about pricing; it is the obstructive way which publishers prevent wider access to their published material which also causes concern, and their apparent conservatism with regard to pioneering innovative approaches to STEM.

Having pointed out the financial challenges facing commercial journal publishers, the context within which UK publishers operate need to be considered. This includes establishing where the UK fits into the global scheme of science research.

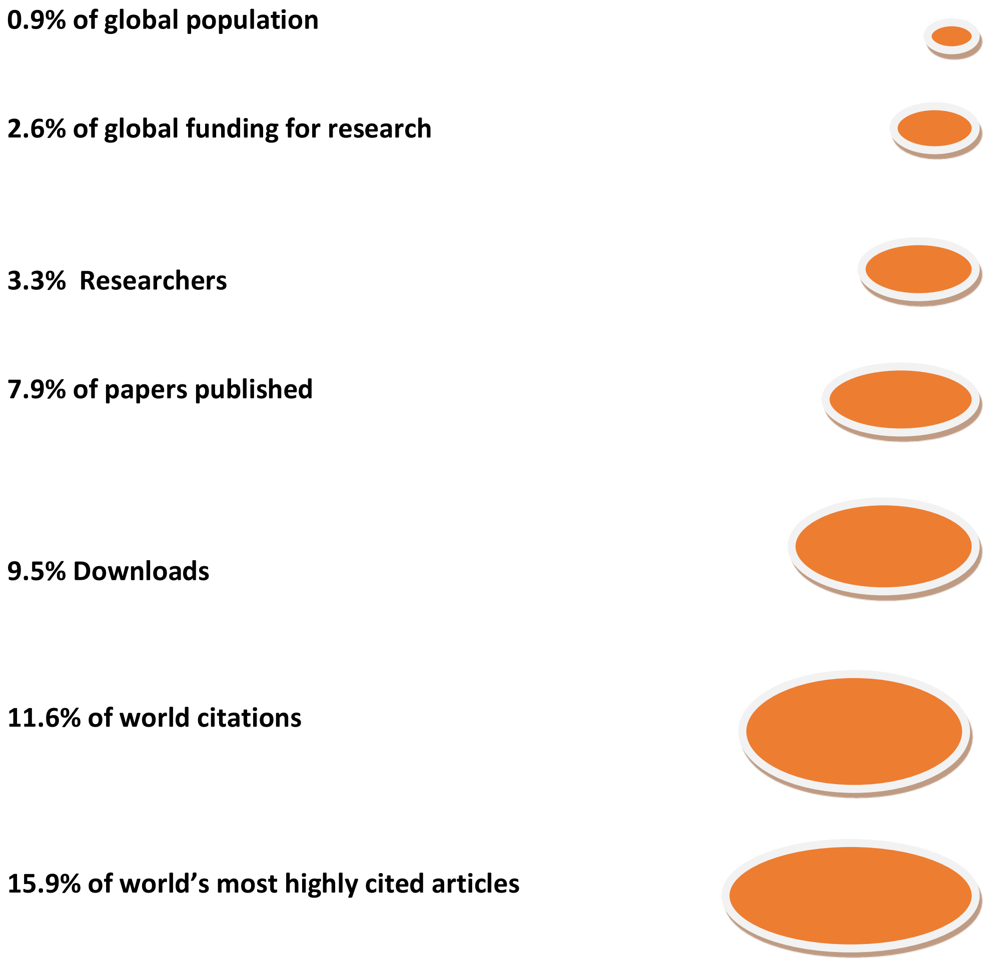
6.3.7. UK status in scientific research

On one hand UK's research programme has become increasingly global in outlook. There is collaboration with researchers in other countries, and Science itself is moving towards an open and democratic system which knows no geographical boundaries. On the other hand, UK research is competitive and introspective, seeking to support national innovation and scientific excellence in its universities, and also to protect the individual intellectual property of the researcher/author. This is a difficult balance for STEM to sustain both politically and operationally.

There is an observation that the 'UK punches above its weight' in science and this includes a well-roundedness of research across most disciplines (UKDBIS, 2009; Elsevier, 2013). Whilst the UK represents just 0.9% of the global population, 2.6% of R&D expenditure, and 3.3% of researchers, it accounts for 9.5% of downloads, 11.6% of citations and 15.9% of the world's most highly-cited articles (UKDBIS, 2009). Amongst its comparator countries, the UK has overtaken the US to rank first by field-weighted citation impact (an indicator of research quality). The UK is recognised as being highly productive in terms of researchers, articles and citation outputs per researcher as well as per unit of R&D expenditure.

The following chart puts these issues in a quantitative context.

Graph 6.6. UK's share of global demographics and stem (2009)



Source: Based on graph in The Royal Society's "The Scientific Century: securing our future prosperity" (Taylor, 2010) and (UKDBIS, 2009) and Elsevier, 2013..

However, the UK's share of worldwide R&D and also its share of worldwide researchers have both been falling. This is reflected in the following:

Year	*UK worldwide share of R&D*	*UK Share of worldwide researchers*
2007	3.1%	3.9%
2009	2.8%	3.7%
2011	2.7%	3.4%
2013	2.6%	3.3%

Source: Unesco, 2015

This has had its impact on UK's share of worldwide scientific publications over the years. In 2007, UK's share was 14.0% of scientific articles; by 2013 this had fallen to 6.9%. (source: Unesco, 2015).

During phone interviews with individuals in the UK academic sector and abroad (see meetings referred to in Methodology chapter 3), international collaboration and researcher mobility were acknowledged as being important in maintaining UK's prominent position as a scientific research nation. UK researchers are not only highly collaborative and mobile across international borders, they are mobile between academic and corporate sectors within the UK. Traditional institutional and geographic boundaries are breaking down for research activity.

This is important for UKWs - the research structure is becoming more open and de-fossilised.

6.3.8. UK's R&D Industry

Several countries have business sectors which invest more in R&D as a percentage of their gross domestic product (GDP) than the UK. In the international stakes the UK falls behind the Asean tiger economies.

R&D performed by businesses as a share of its GDP in 2013

	R&D as % of GDP
South Korea	3.26%
Japan	2.64%
USA	1.92%
Germany	1.09%
UK	1.09%

(source: Unesco, 2015)

Different figures have been made available in Elsevier's 2013 survey of the UK research sector for the Department of Business, Innovation and Skills. The Elsevier study indicates that funding of R&D is proportionately lower in the HE sector and business sector than for most comparator countries. As shown by the Unesco figures above, South Korea, Japan, China, USA and Germany all exceed the UK in terms of proportionate investors in domestic R&D programmes.

The Elsevier report for DIS (Elsevier, 2013) also shows the distribution of funding sources and the sectors where R&D is performed for 2011.

UK Research and Development (GERD) by source of funding:

Sector	R&D Funding	% of Total
Business/private sector	£12.6 billion	46%
Higher Education	£0.3 billion	1%
Government R&D	£8.3 billion	30%
Other	£6.2 billion	23%
UK R&D by sector of performance		
Business/private sector	£17.4 bill	64%
Higher Education	£7.1 billion	26%
Government R&D	£2.9 billion	9%
Other	£0.5 billion	2%

R&D performance is proportionately greater in the Higher Education sector in the UK, but lower in the business/private sector than most of its comparator countries. "R&D as a business sector is considered a driver of short-term economic growth" (Elsevier, 2013).

Within the UK there is little consistency in the statistics given for R&D being undertaken within the non-academic sector specifically. The following tables give the overall dimensions according to two sets of national R&D data.

Table 6.6. UK R&D in UK Professional and Engineering Sectors

Professions	Numbers Employed	Number of Firms	R&D Data	
			ONS Data (2008 in £m) (A)	BIS Data (2008 in £m) (B)
IT strategy and planning	1,074		675	
Technology hardware		72	1,573	1069
Mobile communications		11	1,411	377
Telecommunications		3		1,122
Civil engineers	78,669	16		69
Oil and Gas production		6		1,348
Mining		7		426
Industrial engineering		59		382
Aerospace and Defence		34	1,714	1,707
Mechanical engineers	67,914	31	1,037	1,398
General industrial		11		219
Industrial transport		12	1,289	91
Gas, water utilities		11	33	56
Oil equipment services		10		48
Design & Development eng	46,899		587	
Personal goods		7	15	30
Leisure goods		12	33	198
Production & Process engineer	19,823			
Forestry and Paper		2	49	11
Planning & Quality engineering	18,465			
Electrical engineers	44,565	10	569	81
Electronics engineers	22,992	104		671
Quantity surveyors	41,236			
Household/home		13		215
Bioscientists and biochemists	42,074			
Food producers		26	305	1,132
Beverages		6		25

Tobacco		2		144
Pharmaceutical/Pharmacology	37,670	134	4,321	9,592
Chemists	16,055	57	628	543
Chemical engineers	4,294	76		
Physicists, geologists,meterol	8,435		90	
Industrial metals		2	63	92
SUBTOTAL ENGINEERING & INDUSTRY	578,165	734	14,392	21,046
Medical practitioners	204,350	43		353
Software professionals	277,408	154		1,623
Solicitors, lawyers, judges	150,043			
Management consultants	136,615			
Life insurance		3		103
Accountants (certified & chart)	128,402	26		207
Bankers		7		1,604
Social workers	99,979			
Accountants (management)	54,158			
Architects	45,933			
Dentists	33,098			
Public service workers	24,993			
Psychologists	22,015			
Town planners	21,187			
Legal profession nec	17,164			
Opticians	13,833			
Veterinarians	12,282			
Probation officers	12,007			
Social science researchers	8,944			
R&D support	403			
Wholesale & Retail	75			
Miscellaneous	500			
SUBTOTAL SERVICES	1,263,314	233		3,890
Not listed above			1,712	111

TOTAL	1,841,479	967	16,104	25,047

Sources: (A) Table SB2 – Expenditure on R&D performed in the U.K. Businesses: 2001 to 2008. U.K. Business Enterprise Research and Development Statistical Bulletin, 2008 (11 December 2009).

(B) UK Department for Business Information and Skills – Scoreboard.

Summary

The STEM publishing industry is stuck in a time warp, conditioned by its profitability expectations and ownership structure which limits any appeal towards experimenting with risky new paradigms which might address some of the criticisms being levied against it by industry pundits. The serials crisis remains a major problem for all stakeholders in STEM. Lack of collaboration between publishers and librarians to find their way through current difficulties as part of its print-legacy, and cooperate on strategies to migrate STEM smoothly into a digital environment, is potentially destructive. There is complacency dominating STEM publishing, with operational decisions taking precedence over strategic initiatives.

The consequence is that there is disinterest in expanding the audience for STEM material from the current focus on academia and corporate R&D to a wider group of professionals, SMEs and citizen scientists.

The question is whether these inherent tensions within STEM will surface and lead to a revolution rather than evolution in the way STEM operates over the next five to ten years. It is a question which can be answered in a number of ways, depending on the status, background and experience of those who address it.

From the perspective of an independent observer it appears that major change will happen, but that it will still have as its basis the traditional book and journal to satisfy the needs of the traditionalists within the research sector. The balance between the innovation and traditional aspects of STEM is difficult to assess without more futuristic studies being undertaken to provide evidence of impact. One important ingredient in this crystal ball is the speed and assimilation of new trends in STEM communication. The agents for such change are analysed in the following section.

6.4. ENVIRONMENTAL AGENTS FOR CHANGE (B)

As reported in the previous chapter, there are social and technical changes about to impact on researchers, knowledge workers and UKWs. In this section the focus is on the STEM information industry as corporate entities and the changes which are anticipated within this sector. These include financial trends, e-publishing developments, policy changes and the changes taking place in how science is being conducted. This complements the previous chapter (chapter 5) where the emphasis was on the changes which will affect knowledge workers. The two sets of environmental changes, working together, will increase the speed of the print to digital transition.

Methodology

The first part of this chapter - STEM dysfunctionality - used mixed methods research (MMR) as methodology, and desk research as the research method. The information sources were varied, ranging from monographs, journal articles, through moderated bulletin boards, listservs, blogs and wikis to items published in newspapers and magazines.

The drivers for changes in this next section focus on the STEM industry and are explored primarily by referring to published monographs, research articles and blogs from leading pundits in the industry. Critical analysis was used to ensure that their views had relevance to this thesis and that they also have credibility.

This section also analyses views from meetings with representatives from the STEM industry, and from quantitative data made available by STEM organisations and sectors. These sources reinforce views given earlier that the drivers for change are incompatible with a tradition-dominated business sector and that a major restructuring of the industry within the next five years will occur, driven by the combination of social, technological and commercial forces.

6.4.1. FINANCIAL/COMMERCIAL

The main complaint about STEM at present is that the publishers’ preferences for charging a toll-based system for access to its publications precludes everyone outside the closed academic/R&D circles from being able to read and use the published research results.

There are other business models which have emerged more in tune with external developments in digitisation and the Internet. The one which has many supporters is an open access (OA) model, one which is reflected in many other open developments in IT, and which also offers potential benefits to UKWs in enabling them to gain easy and free access to STEM results.

6.4.1.1. ‘Openess’ and Open Science

‘Openess’ is a broad movement, part of cultural change. It relates to a move from control to openess and democracy. Specifically, as far as STEM is concerned, it replaces ‘toll-based access’ with ‘free at the point of usage’ as the underlying commercial model.

The concept that ‘Information wants to be free’ was claimed by Brand (Brand, 1984) as early as 1984. He highlighted that information is a strange ‘product’. It does not follow conventional rules of losing its value over time (depreciation) or through frequent usage. In fact the more it is used the more valuable it becomes. Obscurity is fatal for information – it has to be seen and recognised and be cherished, and in so doing does not obey traditional laws of wastage. Brand pointed out that although information wants to be free, it also wants to be expensive – the two concepts struggle against each other (Brand, 1984).

This thought has also been pointed out by Google’s Hal Varian (Varian, 2000) who wrote:

> “Because the marginal cost of reproducing information tends to be very low the price of an information product, if left to the market place, will tend to be low as well. What makes information products economically attractive - their low reproduction costs - also makes them economically dangerous” (Varian, 2000).

The danger is that free access runs up against publishing’s tradition and legacy. Openess conflicts with those forces protecting intellectual property and copyright, which are equally important social movements with strong commercial support and historical roots. This alternative view has been made by Cory Doctorow in his book “Information Doesn’t want to be Free” (Doctorow, 2015) in which he challenges the current state of protectionism in the creative industries. His point is not that information wants to be free but rather people do not want to be over-protected. Protection over rights usually incorporates a charging mechanism, and the extent of this charge is at the crux of tensions between current STEM stakeholders.

A prominent champion in support of the open access movement in the UK has been Jisc. It has funded research studies, several of which suggest that if open access could be implemented by all relevant parties “The increased impact of wider access to academic research papers could be worth approximately £170 million per year to the UK economy” (Read, 2011). Similarly, funding agencies such as the Wellcome Trust have been vocal in their support for open access for the dissemination of results arising from their investments in biomedical research (Welcome Trust, 2008a and 2008b).

Against such libertarian organisations there are the forces of commercial publishers, notably through trade associations such as IPA (International Publishers Association), The International STM Association (STM), the Association of Learned Professional and Society Publishers (ALPSP), and the American Association of Publishers (AAP). These associations have equally deep pockets to fund lobbying activities aimed at supporting a commercial approach to scholarly communication and protection of copyright.

There are several types of open access available to STEM, each being colour-coded. More details on each is given in the Business Plan section of this thesis (see section 6.2.5.1). Each type – grey, green, gold, hybrid – has its own advocates and supporters. So far none has offered a radical commercial approach to STEM.

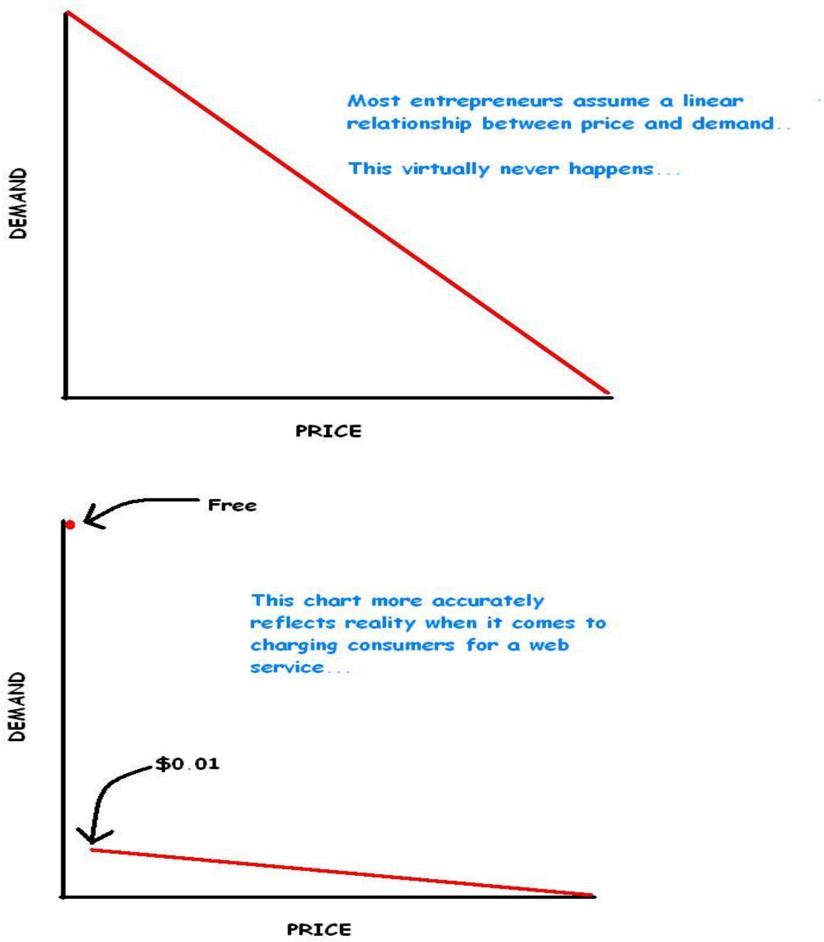
A final report from the University of California and the California Digital Library published in July 2016 attempted to provide the definitive answer to the issue of the consequences of a ‘flip’ from a subscription-based publication system to a full (Gold) open access business model (University of California, Davis, 2016). The conclusion from this $800,000 study funded largely by the Mellon Foundation confirmed what previous reports had suggested – that the move to the Gold system involving payments by authors results in increased costs for those research institutions which are highly productive at the expense of smaller research centres. This 'Pay it Forward' research study included the results from focus groups, author and reader studies, publisher surveys and data analysis of library activities. It highlighted the split personality between users who want to see everyone pay for the publication of their research outputs; as authors they do not want to pay for their results to be published and as such Gold remains a low priority. The study also showed that publishers approached setting the price for the Gold APCs (article processing charges) in a muddled way. The key result is that institutions that consume literature without producing much would save money, but the consequences on the productive research centres could become severe, and the implications this has on the ability and willingness to sustain a Gold open access movement could become profound.

6.4.1.2. Freemium

Openess and free are not the same. Free specifically relates to a commercial transaction. 'Free at the point of usage' has been advocated by Anderson (Anderson C, 2009b) in his book 'Free – the future of a radical price'. He suggests that the Internet will encourage free access to basic information services (such as research articles) with commercial returns being sought from other activities, such as through offering premium services, seeking advertising, gaining sponsorships, etc.

Charging any price, even a few pence, for accessing a research article online would stifle latent demand according to Anderson. "Give a product away and it can go viral. Charge a single cent for it and you're in an entirely different business, one of clawing and scratching for every customer" (Anderson C, 2008a). The difference between 'cheap' and 'free' is what venture capitalist Josh Kopelman calls the 'penny gap' (Kopelman, 2007).

Graph 6.7. The Penny Gap



Source: Josh Kopelman, MD First Round Capital, 2007

In the digital marketplace the most effective price is no price at all. Anderson gave examples where novel business models are applied which include cross-subsidies (giving away a digital recording to sell a TV cable service) and freemiums (offering *Flickr* for free while selling the superior *FlickrPro* to more serious users; the same with *LinkedIn*). Other examples include the music industry in recent years where appearances, streaming, festivals and merchandising reflects that new sources of income can be made from events other than just selling music on CDs.

Anderson addressed the organisational aspects that differentiate zero from any price, suggesting that a zero price should be considered for the main product (such as a journal article) and freemium pricing applied to related premium products. Zero pricing would open up the market for the article and would be sustainable if there were sufficient interest within the sector for the associated premium products for which payments would be sought. This is a drastic course but one which would bring in UKWs as information users, but not necessarily as buyers.

Adopting a freemium pricing policy is a big ask for a traditional, conservative and protectionist-focused STEM journal publishing sector, and not one which has been readily adopted by the commercial STEM publishing industry. The market profile for any digital good or service is not smooth – there are areas of intense concentration (the 'core') and a large part of the market involves little activity (the 'tail').

6.4.1.3. 'The Long Tail'

The 'Long Tail' concept takes into account that there may be individuals who change their behaviour as a result of the digital revolution, but it is the mass of people who are not in the forefront of developments but who could become casual users, which could become important. At present, within STEM, they - UKWs - remain latent knowledge workers.

Anderson, editor of the *Wired* magazine, unleashed a global debate with an article entitled 'The Long Tail' in October 2004 (Anderson C, 2004; 2009a). The term has caught on in technology and media circles. The long tail is the large portion of content that is thought to be of residual value to companies catering for mass audiences. Anderson claimed that this residual portion of the demand curve (see below) is both significant and in many instances profitable. It opens up a market opportunity which needs to be considered in assessing business models.

'The long tail' is the thousands of products that are not number one bestsellers. In the digital world, these products are booming because they are unrestricted by demands of physical retail space, as is the case in the pre-digital age. What once had to be stored and accessed from physical buildings and shelving in warehouses now live on in computer memory and can be retrieved quickly, easily and inexpensively using online systems.

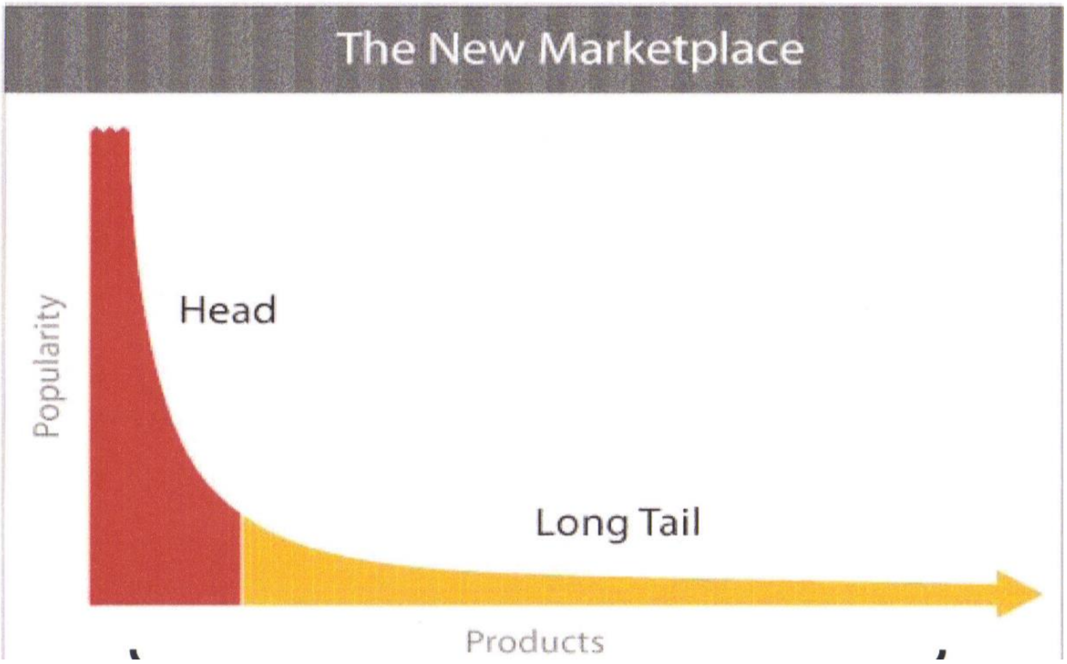
Anderson claims there is still demand for big ‘cultural buckets’ or hits (such as subscription-based journals for academia), but this is no longer the only market. The hits now compete with an infinite number of niche markets. The mass of niches always existed, but as the cost of reaching them fell – consumers finding niche products and niche products finding consumers – this concept becomes a cultural and economic force.

Anderson says that in an era of almost limitless choice, many consumers will gravitate towards popular mass-market items, but just as many will move towards items that only a few, niche-market people want. Until recently, mass-market entertainment ruled the industry. In the digital age the tail exceeds the core markets in many instances. Specialism flourishes. Latency is breached by technology. Niche products available for niche markets are made available in a way which challenges the dominance of a ‘hit’ focused culture.

“Amazon has found that 98% of its top 100,000 books sell at least one a quarter” (Anderson, 2009a). Perhaps more revealing is that a further one-third of their sales come from titles not in the top group, suggesting that the market for books not held by the average bookstore is already one third the size of the existing market. “Apple has said that every one of their one million tracks in iTunes has sold at least once”. “Netflix reckoned that 95% of its 25,000 DVD’s …. (was) rented at least once a quarter”. These experiences quoted by Anderson show the power of the long tail in changing industry paradigms and raising the spectre of the long tail as an important business concept (Anderson, 2009a).

According to Scopus (2008-2012) 80% of article citations come from 20% of articles (however, unlike the above services, 32% of articles were uncited)

Graph 6.8. Theory of the Long Tail



Based on Wikipedia's description of Anderson's Long Tail, 2004

Nevertheless, research publishing displays aspects of the long tail. On the supply side, there are a few large commercial and society publishers complemented by thousands of smaller publishers. On the demand side, users of published information are mainly in the university and corporate research centres worldwide but they are surpassed in numbers by trained and educated knowledge workers in wider society, particularly the UKWs.

As described by Brynjolfsson et al (Brynjolfsson, 2007),

> "We find consumers' usage of Internet search and discovery tools, such as recommendation engines, are associated with an increase in the share of niche products. We conclude that the Internet's Long Tail is not solely due to the increase in product selection but may also partly reflect lower search costs on the Internet. If the relationships we uncovered persist, the underlying trends in technology portend an ongoing shift in the distribution of product sales".

The claim being made in this thesis is that tipping points and long tail concepts – both related in their approach to defining new marketing approaches - are significant business and social drivers towards effecting change in the STEM publishing sector over the next five years. Both are strong influencers in bringing UKWs as users into the scientific effort.

6.4.1.4. Tipping points

The Tipping Point highlights that a traditional approach, such as in communicating scientific research results, undergoes a dramatic change as a result of external events. These events are often outside the control of the affected community.

In 2000, Gladwell pointed out that there is not always a smooth transition from one business paradigm to another (Gladwell, 2000). According to Gladwell in his book "The Tipping Point – How little things can make a big difference" change and innovation does not always take hold for logical reasons. Gladwell claims that successful ideas, products and messages behave as 'epidemics' or 'viruses'. They are contagious. He also suggests that there are three rules which set off an epidemic.

1. The first is the *Law of the Few.* A few individuals can have a significant influence in creating change. They are described as connectors, mavens and salesmen. Connectors know many people – the average personal contact network is claimed to be about 150 people (Dunbar, 1992) or 262 as the average *FaceBook* user (Arbiton, 2013), but connectors know many more, now more than ever due to social networking. They have extensive personal and online contact networks with whom they communicate . They are on first name terms with the movers and shakers in industry. Mavens are individuals who are very well informed and share their knowledge willingly - they accumulate and disseminate knowledge. They are not persuaders – they are teachers. Finally, salesmen have the power of persuasion. They tend to be subtle in their approach. Their arguments cannot be resisted.

Elements of these three processes effect change. There are candidates who could be considered connectors, mavens and salesmen in the current controversies over aspects of scientific communication – notably in the area of Open Access (OA) adoption. Experts such as Harnad

(University of Southampton) and Guedon (University of Montreal) may be considered as members of the law of the few.

2. The second rule of the epidemic is for '*stickiness'* in the message. For electronic publishing this can be a technologically 'better' information service – a key stickiness factor. The message should have recognisable appeal and offer tangible benefits. New alternative research output systems fall into this category as long as the value to the end user of adopting these new ways of disseminating research results is clearly apparent.

3. The final epidemic is the *power of context*. Epidemics are sensitive to prevailing conditions. Starting an epidemic involves a different set of human profiles - innovators, early adopters, early majority, late majority and finally the laggards. The first two are visionaries and risk takers, whereas the early and late majority and laggards avoid risks - they are pragmatists. There is a chasm between the two groups. This is where the connectors, mavens and salesmen have a role in generating the epidemic. They translate the message from the first group to the second.

The issue here is that there are social mechanisms behind changing attitudes. This is as relevant in electronic publishing as elsewhere. It means technological efficiency by itself is not enough. There also has to be a social support mechanism in place.

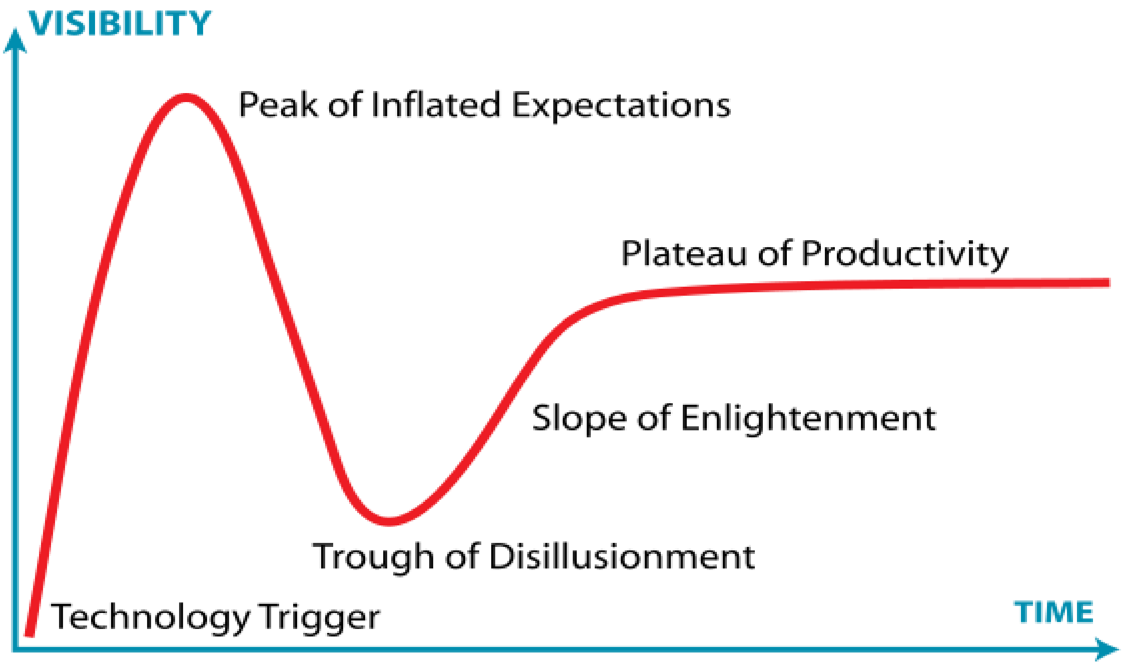
Have the more significant aspects of electronic publishing reached tipping point? Several have, whereas others still have some way to go. STEM publishing still need the connectors, mavens and salesmen to be more active – for example several recent author studies show that, despite the claimed advantages for authors having their articles published in open access format, as many as 90% of authors are still unconvinced (Nicholas, 2010b). 'Tipping point' issues have not yet taken hold across the board within the research author community.

This is relevant for UKWs as there is a high degree of fragmentation within UKW groups, and each fragment has little experience in adopting and using STEM publishing systems. Ensuring that epidemics take hold in every UKW sector may prove difficult. However, in combination with the following concept which describes how new STEM products and services reach maturity, it suggests that there are systemic market forces at work which can change UKW attitudes towards the adoption of STEM output and how it may be disseminated in future.

6.4.1.5. Product Life Cycle

At a product level, the Gartner 'Hype' Cycle demonstrates that different digital products are at various stages of development, and all go through a period of hype and disillusionment before settling down on an even keel (Gartner, 2014).

Graph 6.9. The Gartner Hype Life Cycle



Source: Based on Gartner's Hype Life Cycle in Wikipedia

As a concept the Hype Life Cycle model helps organisations understand that the path to market acceptance for a product/service is not smooth and that disappointing results may be a reflection of the uneven nature of the product life cycle.

Specifically, the above chart illustrates how various stages which STEM information services can be plotted onto the Hype model. It is a dynamic model as well as a subjective one. For example, although institutional repositories (IRs) could be placed as being at an early stage – at 'technology trigger' – in recent years there has been commitment by funding agencies to move them up the slope and beyond the ‘peak of inflated expectations’. Web 2.0 may be entering the ‘trough of disillusionment’ according to some pundits, whereas digital rights management (DRM) may be on the ‘slope of enlightenment’ or even reached the ‘plateau of productivity’. Social networking and social publishing for the science community may still be anticipating a ‘peak of inflated expectations’ and therefore have some way to go before they become productive tools in STEM.

The importance of this concept is that good new ideas may fail or be slow to be adopted just as often as they achieve dramatic early commercial success. There is a ‘right time’ and ‘right condition’ for new services to be introduced successfully (the ‘tipping point’).

Unaffiliated knowledge workers are bystanders in seeing how such new products/services succeed or fail along the hype cycle. However, in future their combined influence, attitudes and approach may have the effect of changing the position of new digital information products or services on the Gartner Hype life cycle model.

6.4.1.6. Economies of scale

Many new STEM products and services which meet conditions set by the digital research environment require investments to be made in technology and IT expertise. The structure of STEM publishing is such that large commercial STEM publishers - such as Elsevier, Springer S&BM (and Nature), Informa (Taylor and Francis) and Wiley (Wiley-Blackwell) – operate at one end of the scale/size spectrum, and the small, highly specialised and focused learned society publishers or university presses at the other. It is not just a matter of corporate size. It is also focus, sophistication and professionalism in the adoption of appropriate commercial/business policies. The tail of the STEM publishing sector does not have the scale, resources or even commitment to undertake risky investments in new informatics areas.

Traditionally, learned societies saw their publication programme as an asset for their members, making sure that latest research in their field was published through the learned society’s imprimatur and own journal. However, in recent decades several learned societies began subcontracting the management of their publications to larger commercial companies. Economies of scale are important when reaching out to a global audience.

A sophisticated sales and marketing apparatus is required which can only be sustained if there is an extensive range of products being sold. It also requires an investment in production and IT skills to support the transition from print to digital publishing, which adds to the cost base of the STEM publisher. Small publishers and learned societies are unable to commit such resources if it means that other aspects of their corporate mission are compromised (see chapter 7 on Learned Societies).

Increasing corporate size to benefit from economies of scale is not without negative consequences. According to Professor Nerissa Russell, anthropology, chair of Cornell University Faculty Library Board:

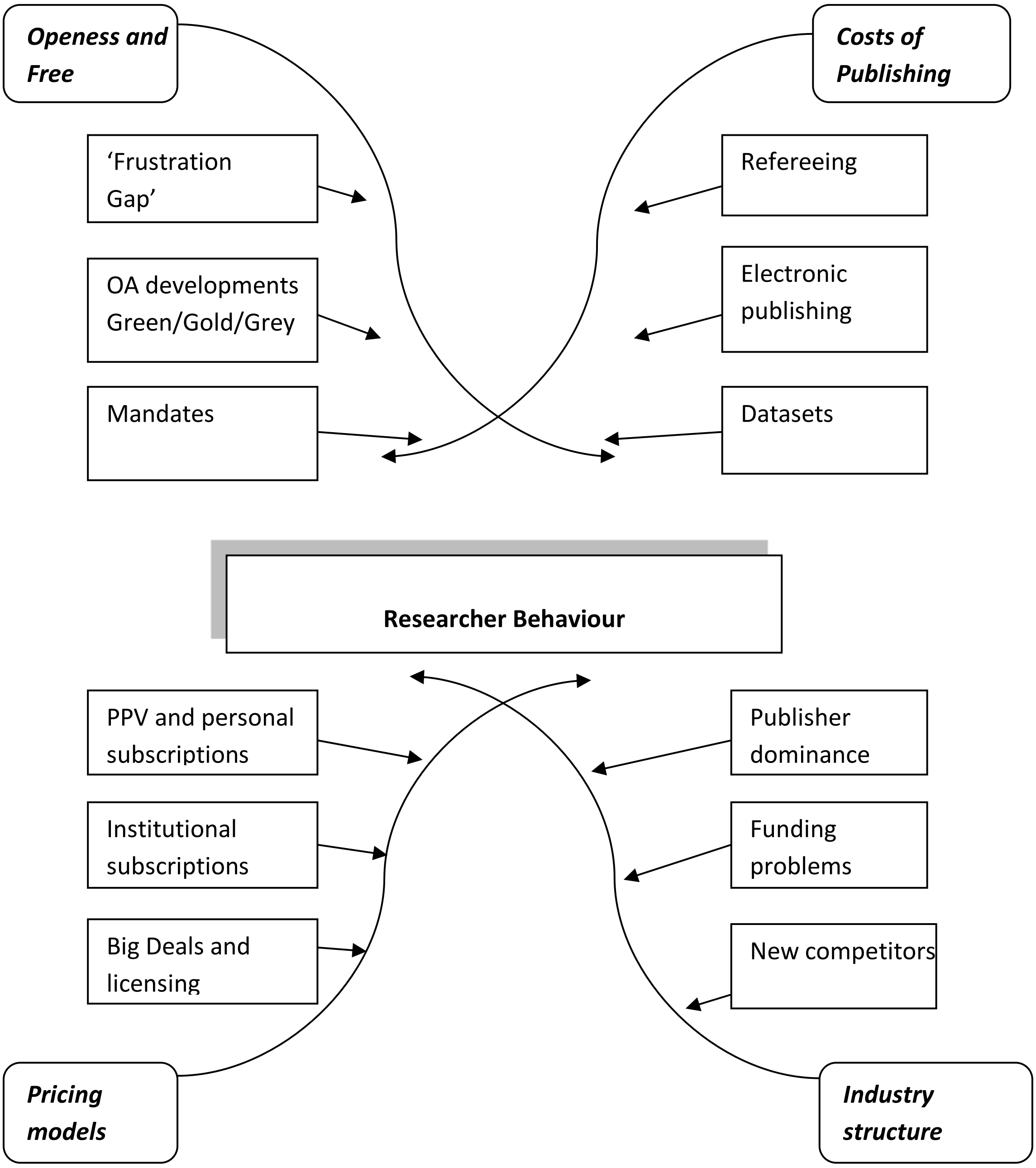
> "There's been tremendous consolidation in the publishers, and things that used to be published on their own by learned societies are now being contracted out to these commercial publishers. There are about five commercial publishers, and they're jacking up the prices to make money because they can." (March 2014, Faculty Senate Meeting, Cornell University).

Larger commercial publishers have offered their more sophisticated online infrastructures and support services to small learned societies, and particularly to incorporate learned society titles within commercial publishers' portfolios. In effect larger publishers are buying market share on the back of the smaller learned society publishers. Small publishers benefit from giving their journals global exposure, and in some cases getting more revenues than they would have otherwise received.

This raises problems for UKWs as their usage and publishing activities are controlled by policies set by the commercial sector which are often more restrictive. However, the more cost effective digitisation of research output becomes the quicker the traditional barriers created by economy of scale can be lowered and dismantled and learned societies regain their position as primary providers of STEM.

The following chart plots some of these Economic and Financial trends and how they come together in changing research behaviour of researchers.

Model 6.10. Economic/Commercial Trends



6.4.2. PUBLISHING AND STEM DEVELOPMENTS

A key function of the STEM publishing process is that it provides the structure for weeding out noise and inaccuracies in research outputs, enabling researchers to focus on the relevant, accurate and useful. The role of the refereeing system is crucial. However, there are challenges to the current two 'blind' refereeing procedure which most journal publishers adopt in order to ensure that article quality is incorporated into the minutes of science.

The refereeing system remains the main solution to one of the leading problems facing the STEM industry – that there are too many research outputs for an individual researcher to cope with. There is an information overload.

6.4.2.1. Information Overload

Discussions about research information and users frequently is about is how, in a digital society, people cope with too much information being published in too many sources. An early proponent of the concept of 'information overload' was Toffler (Toffler, 1970) who claimed in his book "Future Shock" that this was a psychological syndrome experienced by individuals rendering them confused and irrational.

Whereas information overload used to be considered a psychological problem by Toffler it is now viewed as a cultural condition. Industry observers now worry that it is not too much information we are getting but rather not enough knowledge. Two possible solutions have emerged – individuals rely on arithmetics, the reliance on large databases to collect and sift information on their behalf. Alternatively, or in addition, the social construct of using colleagues, societies, professionals and friends to point individuals to relevant items is employed (Dean & Webb, 2011). According to Shirky (Shirky, 2008), any problem we have with information overload is a filtering failure. Whilst in a pre-digital world we relied on traditional quality sources such as newspapers, journals and textbooks for filtering, in the digital world there has been a shift towards the informal and social media as providing filtering support.

Jan Velterop, has commented that there is now so much information available in any given field, more than anyone can find using traditional literature searches. "The time is long gone when it was possible to go to a small set of journals to find pretty much all needed". (Velterop, 2014).

There are two problems resulting from this. Firstly, researchers arrive at conclusions based on a small subset of information available in the area concerned. Secondly, Velterop claimed there is much duplication of research as researchers are no longer aware of similar and related activity going on elsewhere. As both these factors “will only add to the noise and volume within the system, the situation promises to get progressively worse” (Velterop, 2014). Furthermore, academic discovery often takes place in the ‘interfacial’ areas between disciplines.

Another aspect is that there is a finite amount of time available for researchers to find what they are looking for. The result is that a researcher’s focus could become too narrow, that they can be side-lined by new developments, and spend too much time going down blind alleys. In addition, disciplines change their shape and direction which could be overlooked by individuals in their focus on a specialist area.

More worrying is the impact which the trend towards ‘multi-tasking’ is having on the ability of researchers and academics to absorb information. Multi-tasking introduces a distraction. From studies on students it appears that their performance is lower in comparison with those who do not multi-task (Greenfield, 2014 p230). Increased availability and use of *FaceBook, Skype* and messaging systems are impacting negatively on concentration levels. Besides information overload in content, the digital native faces information overload through new media formats - both the medium and the message creates problems (see McLuhan, M. 1964).

The net result is that users of research information find their own way through the mass of information with which they are confronted – some are successful; others become confused (see Typology of Researchers in section 5.13.1).

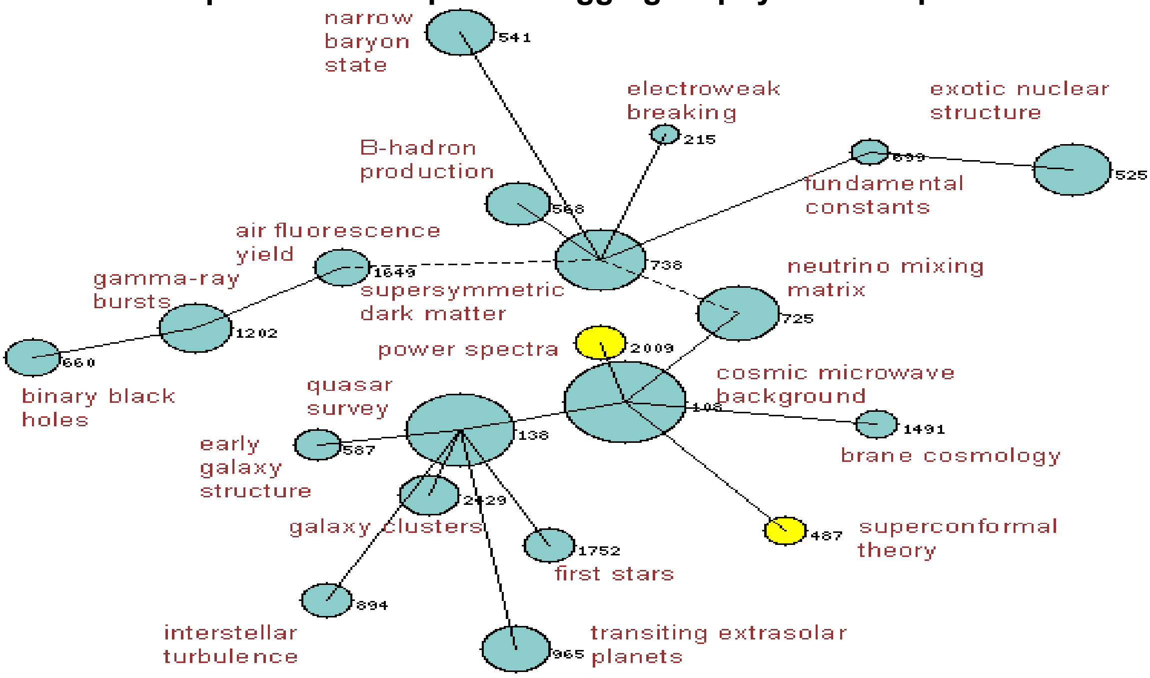
The problem gets worse as the structure of science splinters in different directions, each creating new sources for research outputs and publications.

6.4.2.2. The Twigging Phenomenon

New subject areas are created continuously as frontiers of Science are pushed out ever further. Science fragments into smaller sub-disciplines – the so-called ‘twigging phenomenon’ (Small, 2006). Each new sub-discipline is a collective ground for a group of like-minded researchers to unite and create a new learned society, and this leads to the development of a common forum for the exchange of relevant information – a society-spawned learned journal. Such groups want the published output from their members to receive international recognition, respectability and visibility.

A similar process is engaged by commercial journal publishers; their in-house editors are constantly looking for new publishing ventures which support new research areas. The following graph is indicative how such twigging or splintering occurred in one sub discipline of physics – the same process is replicated in most areas of science.

Graph 6.11. Example of 'twigging' in physics disciplines



Editorial barriers to entry are low in STEM publishing, and getting lower as 'economies of scale' bite further. It is a competitive process with each publisher seeking to be the first to establish a journal or book series in any new splintered research area, to sign up the best editor-in-chief, to invite support from a reputable editorial board, to offer the best service to authors in the topic. Each such title would be unique even though like-minded titles focus on the same area – they are not necessarily substitutable as each carries different reports and research findings. They differ only in perceived personal assessment of quality and brand, something which is still subjective and unquantifiable (impact factors notwithstanding).

The twigging process adds a further dynamic to STEM publishing – as research frontiers are breached with new research areas, topics and disciplines emerging, the scope for including more and more specialists within the research network increases. Twigging therefore caters for the 'long tail' of publishing and appeals to those UKWs who seek only the occasional specialist publication and occasional research involvement.

However, this structural feature of science makes the information problem facing individual researcher's worse – their exposure to information overload is increased as the frontiers of science are extended. This is where the refereeing service offered by STEM publishing comes into play. The question raised by many pundits is whether the current refereeing process is fit for purpose in a digital age. There are alternative systems which technology is opening up.

6.4.2.3. 'Wisdom of the Crowd'

It is claimed in this thesis that the present STEM publication system caters for the 'elite' - without implying any negative or positive connotation. There is a closed network of specialists who determine what is published. 'Wisdom of the Crowd' has been held as a challenge to such elitism. It has been shown that the sum knowledge and experience of a large number of people exceeds the performance and results of a few skilled experts under certain circumstances. As a social concept it is another move towards the principle of 'democratisation' and against 'elitism'.

'Wisdom of the crowd' takes the position that citizens contribute to a common end from the perspective of their personal interests, background and experiences. In his book, Surowiecki suggests that answers, and therefore ultimately wisdom, comes from asking a wide group of people their opinion on a topic. In many cases the combined results of the group's opinion turns out to be more accurate than from relying on the views of a few individual experts (Surowiecki, 2004).

Surowiecki's theory was based on practical observation. In 1906 Galton witnessed bets being placed on the weight of an ox at a west-country fair in the England. He found that the average estimate from the 800 or so participants was almost accurate. The conclusion from this and similar experiments was that groups do not have to consist of clever people to be smart. Consensus among the masses is achieved through a mathematical truism – if enough people participate the individual errors in their estimates, positive and negative, cancel themselves out. Surowiecki suggests that one should stop chasing an expert and instead ask the crowd to reach informed decisions.

Expertise - as in the current refereeing system - is only relevant under certain conditions. Experts are more likely to disagree than to agree. There are some spectacular examples of the elitist refereeing system getting things wrong – bad research being applauded, important research trivialised and plagiarism institutionalised – though these are untypical. Such failings can be attributed to the current global community of referees being overworked (Ware, 2005). Ware highlights that a small number of referees are responsible for a significant share of articles reviewed – an unhealthy reliance by STEM on the voluntary actions of a dedicated few reviewers. (Article reviewers are rarely paid - they contribute their reviews for the good of science).

New online systems can compete with traditional assessment systems in terms of speed, interactivity and effectiveness in stimulating community involvement. Blogs and wikis are examples of grass roots services providing a framework on which alternative refereeing services could be based, revelling in the democracy which is implicit in the Internet. They are based on the institutionalisation of sharing, cooperation and collaboration which are powerful features of the digital/Internet world (see section 5.9.3.1/2).

Social media and social networking processes, enabled by the Internet's openness and interactivity, could support a different assessment system – one which leads to new publication formats (such as 'the article of the future' (Elsevier, 2011 and Zudilova-Seinstra, 2013)) rather than relying a 'static' published article as the traditional form of scientific communication.

In society there are web sites which ignore the 'expert' and use mass participation by the net generation to create content, assessments and reviews. For example, RottenTomatoes.com, uses the wisdom of the crowd to rate films and movies. Tripadvisor.com does the same for hotels and travel services. It allows anyone to be a critic, not just those who are professionally trained. Even Google's core search system is created using wisdom of the crowd – the

PageRank algorithm (which highlights items most relevant to a specific search) is based on actions by the crowd of its online users. The crowd's vote is encapsulated in the web logs, and search results are raised in the listing of results according to the term's web log popularity. Amazon, e-Bay and similar online services look to the wisdom of the crowd to improve their own approaches to pointing to relevant items for end users to buy based on the experiences of the masses. Wikipedia is an example of a product which has been built up using the wisdom of the crowd in a structured way.

These are not always without fault – some abuse the openess of the wisdom of the crowd assessment - but they do offer another option to a closed refereeing system.

For 'crowd' one could substitute 'unaffiliated knowledge workers'. They are not all experts, but in using the sum of all their experiences they are as likely as not to come up with assessments based on numerical superiority which are comparable in accuracy with the current two-blind refereeing system. It is another way that UKWs could become more active participants in the STEM in future. It would need an alternative refereeing structure to be developed to formalise such a process. The power of technology and social change may provide such a stimulus.

There are indications that Google could be a catalyst for one such alternative to the role of experts. Their extensive in-house research into user behaviour is producing a mass of software algorithms which, taken together with the massive database of electronic content on their systems, could provide the automated basis for quality assessment in future.

Nevertheless, not everyone is convinced, and there are strong supporters of the role which experts play in STEM. One of these is Andrew Keen.

6.4.2.4. Cult of the amateur

Keen, in his book "The Cult of the Amateur" (Keen, 2007) lamented on the growing democratisation within media and suggests that it is destroying something valuable within society – quality, relevancy and expertise. He claims that empowering the amateur, a consequence of passing control to the 'the crowd', undermines authority of experts who have spent years building up personal knowledge bases. Adopting the principle of wisdom of the crowd would give experts the same status as an ignorant bystander, in his opinion. Mumford called such a situation "a state of intellectual enervation and depletion hardly to be distinguished from massive ignorance" (Mumford, 1974).

Keen claims it is necessary for experts to sift through what is important and what is not. Otherwise we are left to make our own way through the mass of 'white noise' without gatekeepers being there to provide selection, advice and assistance.

This is a key plank of the STEM publishing industry. STEM publishing provides the service which enables experts to make assessments, a valuable service for end users and one for which he/she should be expected to pay. Traditional two-blind refereeing (whereby two experts gave their opinions on whether an article merited publication) is a service which needed to be organised – it was not something which emerged automatically, and nor was it free to administer and coordinate.

However, though there are aspects of the 'cult of the amateur' which are important, the STEM communication industry is not static – it is being driven by environmental developments which changes the industry, including the way relevancy is created and targeted to those who most need it. Refereeing could become more open and transparent in a digital world because of general support for open systems.

Though the challenge made by Keen is a fair one, it is one which will be eroded as and when demography provides a more enlightened and extensive crowd or audience. At that stage the 'cult of amateurs' becomes an informed, extensive and workable network of 'amateur scientists' who could interact online to comment on the quality of research activity in an analogous way to that seen with many social media services (Google, Amazon, et al).

Wisdom of the crowd raises questions whether professionalism inherent in the production of content constitutes an unacceptable barrier to widespread dissemination of research output in a digital world. Whether the existing in-house editing skills within publishers, and content management expertise within libraries, restrict the ease of access which UKWs need in order to become active

STEM participants.

6.4.2.5. Miscellanised information

In his book entitled “Everything is Miscellaneous - the power of the new social order” Weinberger, a marketing consultant and fellow of Harvard Law School, extols the virtue of redundancy in a digital age as a counter to such professionalism (Weinberger, 2007).

Metadata facilitates access to objects in different ways. Digitising everything enables information to take on different forms. Whereas in the printed world the ‘leaf can only be on the one branch at any one time’, in a digital world this is no longer true. Metadata provides the link to objects in multiple ways. ‘Messiness’ now becomes a virtue. Unacceptable in a print world, but in a digital world entirely possible as a variety of novel links can be followed to the required published objects.

Weinberger claims that in a print world there was a finite resource to transmit information and hence knowledge. In the new digital world there is no such limit. “Miscellanised information is information without borders” according to Weinberger. Anyone can participate in the information process. This does create noise but it is noise which finds its own level, selection (and community).

According to Weinberger, compilation of metadata should not be confined to the rigid structures of traditional classification/cataloguing. It does not have to be so structured to defy creation or use by a non-professional. Rather metadata should be created, enhanced, built on by the community itself for different purposes, in a sort of Wikipedia style of ongoing self-improvement.

In effect Weinberger claims that the elaborate classification of information will be made redundant by what he refers to as the ‘third order’. The ‘third order’ is social networking/social collaboration through Web 2. Weinberger’s arguments rest on the concept of the ‘wisdom of the crowd’ (Surowiecki, 2004) and the power of metadata fragmentation (Evans & Wurster, 2000). Both result in a greater variety of digital information and communication formats (‘miscellaneous’) and the decline of the expert (classification).

Authority therefore comes under attack. The owner (the publisher) of the published item used to be in a powerful position. In the online world it is now the end user who is empowered. Sifting is now possible through polling and rating systems (*Digg, Twitter,* Amazon, Google, etc) rather than through reliance on the rigid blind refereeing system.

The underlying theme behind Weinberger's book is that there is latency in the information process waiting for new players to join in, and new technology now allows them to do so. In some areas it is more apparent (astronomy, for example), than others and he makes no comment on those subject areas which rely on a corpus of carefully vetted and structured information which advance the cause of science in particular areas (such as in biomedicine). 'Standing on the shoulders of giants' (Bernard of Chartres, 12th century; Newton, 1668) has little room in Weinberger's analysis. On the other hand, he points to greater democracy of scientific interaction and the widening of the community which can engage in science's creation and use.

6.4.2.6. Ambient Findability

As a result of the wide network of potential UKW involvement in research being tapped by the emerging digital world, there is still a challenge in finding one's way through the mass of data and information which is made available. People are faced with a bewildering array of information formats (magazines, billboards, tv, blogs, bulletin boards, etc), which Morville (and Toffler (1970) before him) claims leads to loss of literacy.

Morville wrote in his book "Ambient Findability" about finding one's way through this flood of information (Morville, 2011). Ambient findability is less about the computer than the complex interactions between humans and information. All our information needs will not necessarily be met easily, he claims. Information anxiety will intensify, and we will spend more time rather than less searching for what we need. 'Information overload' faces resurgence in the digital age. Search engines are not necessarily up to the task of finding what the end user wants. They tend to be out-of-date and inaccurate. However, they are trying to rectify some of the emerging weaknesses by improving their technology. For example, they undertake SEO — Search Engine Optimisation — ensuring that the software throws up results that are most relevant to the end users based on search terms provided.

Whilst search engines pride themselves on speed and specificity, this excludes the subsequent activity the end user has to go through in bypassing 'splash' pages and other interferences in reaching the required source data. (Splash pages on a Web site are what the user first sees before being given the option to continue to the main content on the site).

Faced with the above there are opportunities for new types of vertical search services. Vertical search engine, as distinct from a general web search engine such as Google, focus on a specific segment of online content. The vertical content area may be based on topicality, media type, or genre of content, such as a research discipline. Google cannot be as precise and filtered as a targeted vertical search service (Battelle, 2005). The question is whether these can pull back search activity from the entrenched position large generic search engines have established (Gardner & Inger, 2012). This requires hard work and investment — few publishers have shown any inclination thus far to create such platforms either individually or collaboratively.

Consequently, UKWs are not offered a good service. They depend on the broad sweep of sources collected within Google and similar generic search engines. UKWs rely on 'something is good enough' until an improvement in ambient findability can be achieved and it filters down to UKWs.

Ambient findability as described by Morville is closely associated with the development of portals and hubs (see 6.6.4.1). A vertical front end search system, as suggested by Morville, could link into communities to provide a seamless search and delivery system. Both could then feed into an SDI-equivalent of a personalised STEM service. This will be taken further in a later discussion on future STEM trends (see chapter 6.6.4).

6.4.3. DEVELOPMENTS IN THE SCIENCE RESEARCH PROCESS

Science has become more multi-media in its approach, and produces multi-formats as primary outputs. These outputs, in whatever form, are just as critical to researchers in both affiliated and non-affiliated contexts as the text-based write-up in the published research article. The issues facing datasets and data compilations have highlighted this.

6.4.3.1. Data and datasets

The changing nature of the research process creates demand for access to a project's raw data so that experiments can be replicated in different environments and for different purposes (Padley, 2014). Finding relevant data sources and getting access to them can be difficult, but necessary to avoid duplicating research.

A study by Stanford University in 2005 entitled "How much information?" claimed that there was 5 exabytes of information being created each year. Of this, paper-based information represented – even then – a mere 0.01% of the total. Digital information stored on hard discs was the main source. Even this estimate of 5 exabytes is the tip of the iceberg when more recent social trends are taken into account – information is held on store every time one drives through traffic congestion areas; every flight taken; every online purchase made. 'Digital footprints' are left everywhere as part of daily life and recorded within datasets. Claims of between 3 exabytes and 23 exabytes of the worldwide 'big data' have been proposed. One attempt to put this in context was made by Eric Schmidt (chairman of Google) who says that 3 exabytes are created each day, and that as much data is created every two days as was created from the dawn of civilisation to 2013.

With rapidly evolving technologies that range "from genome sequencing machines capable of reading a human's chromosomal DNA in half an hour (circa 1.5 gigabytes of data), to particle accelerators such as the Large Hadron Collider at the European Organisation for Nuclear Research (CERN), which generates close to 100 terabytes of data a day, researchers are awash with information and data”. (Hannay, 2014).

In STEM circles this has led to new opportunities for research, making use of digital data as a primary resource. Access to digital raw material or data from related research studies becomes significant (Anderson C, 2008b). Building on the shoulders of giants has taken a new twist as these giants take the form of robotic accumulations of hard data deposited in subject-based and institutional repositories. The main disciplines where large STEM datasets exist include astronomy, bioinformatics, environmental sciences, physics and demography amongst others. These data stores can often be accessed for free, and users are often able to feed their own research results into the dataset.

Data has become the new Intel. National and international organisations are making infrastructural commitments to create e-Science and e-Research through investing in grids and data networks. The NSF report on Cyberinfrastructure in the US in 2007 (“Cyberinfrastructure Vision for 21st Century Discovery”, March 2007) and investigations on data and infrastructure by OSI in the UK are instances of policy setting initiatives to cope with the ‘data deluge’ (Hey et al, 2003).

One of the biggest challenges is to bring the small, isolated datasets into the publicly accessible domain. It has been claimed, anecdotally, that such small author-created datasets, often held in cabinets or drawers in the researcher’s office, amounts in aggregate to two to three times the total amount of data currently within the large curated datasets at discipline level. The STEM publishing industry has been slow to provide a platform to support such data collections – only recently has there been industry collaboration on issues such as data citation principles (including the international DataCite network), incorporating the Resource Identification initiative and developing altmetrics usage and evaluation (NISO).

Berners-Lee’s vision of the semantic web has datasets as an intrinsic part of the future intelligent web. However, commercial journal publishers are not part of this burgeoning activity. The challenge which optimising dataset access poses is something which all parties in STEM need to address. There is a role for UKWs to provide input to and receive output from such data collections particularly as many allow unrestricted access.

6.4.3.2. Workflow processes

Building on datasets and related concepts such as ‘mashups’ (combining several types of information content and sources in one single search strategy), research activity has embraced features of workflow management. According to Wikipedia

> “A workflow consists of an orchestrated and repeatable pattern of business activity enabled by the systematic organization of resources into processes that transform materials, provide services, or process information. It can be depicted as a sequence of operations, declared as work of a person or group, an organization of staff, or one or more simple or complex mechanisms” (source: Wikipedia definition of Workflow).

The flow being described may refer to a document service or product that is being transferred from one step to another. Publication of research results occurs at a late stage in the research cycle – prior to that there are a number of project phases, each having need for access to certain types of information. From initial researching the idea, through finding out about competitive studies and teams, to looking for collaborators, to sharing research data, to undertaking original research, and in some cases investigating commercial returns – each phase places a demand on access to different types of data and publications.

Have authors of research articles taken on board the tools available through social media and applied them to their current research procedures and workflows? A study undertaken by CIBER on behalf of the Charleston Observatory (CIBER, 2011) addressed this question. In analysing 2,414 responses from an online questionnaire sent to authors of research reports who – *a priori* – were assumed to have interest in social media, the results suggested that there is still some way to go before there is universal adoption of social media within the wider research processes. Adaptation by the STEM research community seemed at best peripheral in 2011.

In the CIBER study, seven areas of the research life cycle were identified, and social tools which corresponded with each were evaluated. Respondents then rated their use of social media according to their own particular workflow. The most popular social media tool was 'collaborative authoring'. The next most popular use was 'conferencing'. The areas of social media in descending order of popularity were:

- collaborative authoring. Just over 50% used this process.
- conferencing
- scheduling
- social networking
- image sharing,
- blogging, microblogging
- social tagging.

The majority of respondents – these were self-selected as being more likely to be at the forefront of social media adoption – only made use of one or two of the above processes. The highest correlations occurred between those who used blogs, microblogs and social tagging (CIBER, 2011).

It appears that the scope of social tools – to enhance speed and extend the global communication of results – were not then integrated within the main workflow of the researcher/author community, the goals of which are to improve research output, disseminate the results and enhance personal esteem. Without mandates being imposed by funding agencies the application of social tools to the scientific publishing process remains (currently) experimental and marginal.

Integrating UKWs into the complete work process in research could be feasible. There are different skill sets and expertises required in all stages of a research project. The technical and innovative research of the topic is only part of workflow process – surrounding it with commercial, administrative and related contextual inputs takes research from a micro level activity to the macro level, from an academic exercise to one which includes practical skills.

The more this occurs the greater the need for UKWs, with their specialist inputs, to be included in the new STEM information structure.

6.4.3.3. Role of Automation

Several pundits (Lanier, 2011; Carr, 2015) point to the impact which automation is having on how the human creative process is being affected by the ubiquity of software and IT developments. Carr in his book “The Glass Cage” demonstrated that new automation developments are undermining fundamental cultural values as they migrate from introducing efficiencies in the workplace, based on powerful computing capabilities, to a subtle take-over of some of the decision-making activities which have been the preserve of the human mind.

This is in part a result of the software developers pushing the boundaries on what automation can do without being constrained by influences from those seeking to ensure that issues such as morality and respect for cultural values are prioritised. Businesses, which employ software developers, seek to maximise productivity and profit to reduce labour costs and streamline operations. The option of enhancing individual professional skills and expertise, or creating a ‘better world’, is not part of the software developers’ primary agendas. When it comes to the development of commercial software abstract concerns about the fate of human talent cannot compete with the prospect of saving time and money. “Many of the problems that bedevil automated systems stem from the failure to design human-machine interaction to exhibit the basic competencies of human-human interaction” (Carr, 2015).

It may be necessary in future for society to place limits on automation. There is the need to shift emphasis on what might be deemed as being ‘progress’ from that of stressing technological advancement to one in which social and personal improvements flourish. The implication, according to Carr, is that a new form of Luddite may emerge to ensure that robotics does not take over and change the direction which society takes from one of acceptable social determinism to one of focusing exclusively on technological efficiency (Carr, 2015 p163). This may be of little immediate relevance, but nevertheless an issue which may emerge in the next decade as one which the STEM industry, professionals and UKWs will need to address as a policy issue.

6.4.4. SCIENCE POLICY ISSUES

Research policy is often determined by issues which are not related to the research task itself. An instance of the importance of taking a helicopter view of science relates to the ‘frustration factor’ described earlier – where the forces of supply and demand for STEM are out of step. Science and research policies need to consider such historical precedents to avoid inefficient and ineffective research activity.

6.4.4.1. 'Tragedy of the Commons'

The Tragedy of the Commons, as described by Hardin in an article published in 1968, involves conflict over resources occurring between individual interests and the common good. It comments on the relationship between free access to, and unrestricted demand for, a finite resource.

The term derived originally from a situation identified by Forster Lloyd in his 1833 book on population, and was then popularised and extended by Garrett Hardin in his classic essay 'The Tragedy of the Commons' (Hardin, 1968). Under 'tragedy of the commons', public common land in medieval times was grazed upon by sheep until such a time as one extra beast tipped the scales on animal overpopulation and made the local commons useless for all. Nothing could survive on the shared land. All shepherds would suffer not just the owner of the last beast added. "Ruin is the destination toward which all men rush" claimed Hardin. This collapse would happen quickly, totally and was irreversible.

The unwritten assumption by critics of the STEM communication process as it existed until the 1980's was that scientific publishing was headed in the same direction – that at some stage the collective library budget, the finite resource for purchasing most scientific communications, would be insufficient to cope with the ever-expanding STEM output. The system would self-destruct under the strain. As new media and publishers of scientific publications followed their own separate agendas the stresses would be ever greater and the collapse of the system more imminent and catastrophic. The Tragedy conceptualises, in a way unintended by Hardin, the problem facing the pre-digital publication system in which publishers produced books and journals on an uncoordinated basis, and unrelated to budget restrictions facing libraries.

The expansion of a nation's R&D effort bears little relationship to the budgets being allocated by individual institutions to their libraries (see section 6.3.5). Research funding sees a steady increase; library funds for collection development is in relative decline. It indicated that there was something inherently flawed about the traditional mainly serials-based publishing system which perpetuated a distinction between the forces of demand and supply. The two forces were uncoordinated. There was a disaster waiting to happen.

However, this Tragedy of the Commons did not occur within STEM publishing. The switch from a print-based publication system to a hybrid and increasingly digital one has produced (albeit temporarily) solutions which have given flexibility to the buying system, and enabled more information to be bought without causing the library system to collapse. ‘Big Deals’ and ‘collective licences’ are examples. Nevertheless, despite these actions there is still an underlying mismatch between the forces of supply and demand in the STEM publishing system. The demand side is severely hampered by being artificially restricted to a small institutional sector of society.

The new digital age pushes out the boundaries against which the tragedy of the commons would take place. The finite resource is being extended as the Internet makes scarcity less of a factor. Information itself does not follow normal rules of degradation and depletion - the more it is used the more valuable it can become. The paradigm has changed, and with this changed paradigm the forces of demand and supply for STEM research output can be realigned.

The inclusion of UKWs within this realigned paradigm could be a valuable feature to ensure that the new STEM information systems work effectively, efficiently and become sustainable. Quadrupling the potential annual audience for STEM (through graduates migrating from academia into private industry, see section 5.10) adds a new dimension in balancing the supply and demand equation. As such UKW involvement and participation in the new STEM digital age becomes critical. Such issues need to be included within the policy debates on Science and Information policies by national and international funding agencies. These debates would need to be more than just about open access but also about inclusion of new information audiences within the future STEM systems to achieve equilibrium in the supply and demand equation.

6.4.4.2. Future of the Professions

The professions are one group which could be included within a new STEM policy-setting system. As with STEM itself, there are changes taking place which challenge whether the existing infrastructure - learned societies - are also fit for purpose in a digital world. As will analysed in the third of the Results chapters on this thesis (see chapter 7) there are questions whether the old-fashioned approach to running societies can survive, and whether societies themselves will fail to climb out of the 'valley of death' (see 5.16.4).

The same external developments which threaten to undermine STM publishing over the next five to ten years can also be applied to the professions. The issue which is relevant for this thesis is the nature of the replacements which will emerge from the decline. The replacement or support services from the degradation of core learned society functions (Susskind, 2015) becomes a critical strategic issue, compounded in this case by whether UKWs will be included in emergent support operations. In farming out some of the traditional more mundane functions and services offered by professional societies, new sub-professions are created and these have profiles similar to UKWs. As such the UKW sector would become beneficiaries of the restructured professions.

As explored by Susskind in their conclusions (Susskind, 2015 pp 303-308) society faces a choice whereby professions would be allowed continue with aspects of enclosure - giving professional members protection to invest in and benefit from their knowledge base through imposing a charging mechanism - or to promote liberation whereby the knowledge base of the profession becomes part of the commons, a public utility, more openly available. Similar choices may also face those in the STEM industry as concerns over information exclusivity confront the open access movements.

6.4.4.3. National and centralised policy directives

Long-term strategies relating to the output of research and its impact are being set by government agencies such as the UK Department of Business, Innovation and Skills (UKDBIS) and Higher Education Funding Councils (HEFCs). These policies often have short term economic austerity programmes as an important consideration. They seek to balance the annual science budget with other immediate competitive social policies and missions.

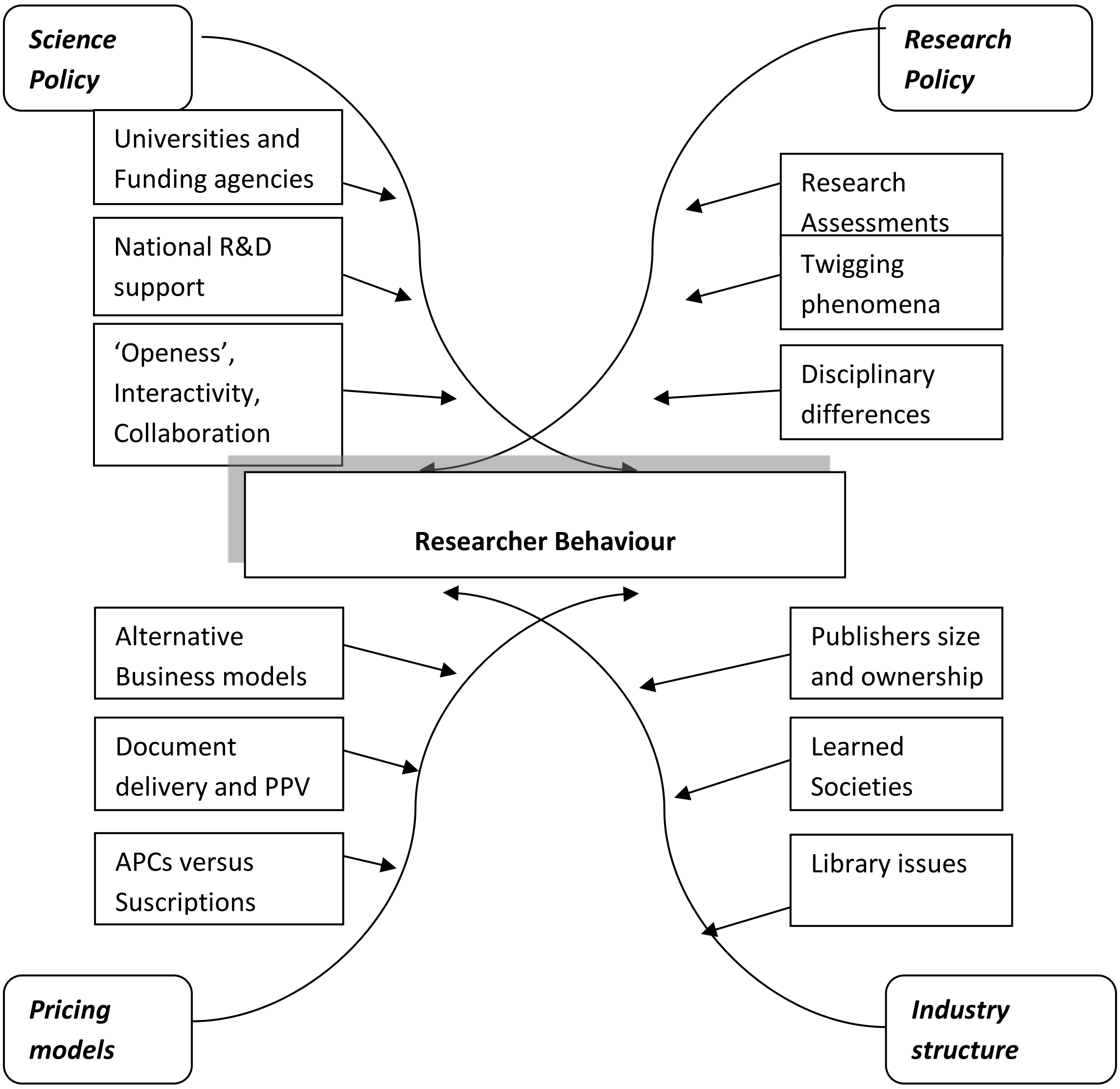
Both public and private funding agencies in the sciences are supporting new measurement standards for assessing the impact and effectiveness of research outputs. This includes within the UK, HEFCE and its RAE and REF assessments, the Wellcome Foundation and the UK Research Councils.

The authority of science lies in its tradition and universal acceptance of quality judgement - notably in refereeing. However, to stimulate originality requires dissent. Tensions facing researchers in balancing these two drives become more strident as improvements in technology tilt the balance in favour of innovation and originality. These two processes, tradition and dissent, are difficult for funding agencies to balance.

At a more practical level, a study undertaken among UK life scientists and their information support needs (University of Edinburgh, 2009) highlights inconsistencies between information search behaviour even within the same discipline, and even within search teams within the same discipline. Exerting a one-fit- for-all policy by science funding bodies is counter to the practical realities of research activity at the coal face. It demands greater research on user behaviour patterns by policy makers *before* making fund allocations which might disrupt effective research activity.

These various political and administrative trends are summarised in the following graph:

Model 6.12. Political/Administrative Trends



6.4.5. The Multiplier Effect

Building on all the above is the 'network and multiplier effect'. This effect increases the rate at which change is brought about through combined interaction of the above concepts. It emphasises that there is a new scientific communication process emerging, and quickly. One which is more in tune with the requirements set by an expanding digitally and Internet empowered society.

Though the Multiplier Effect has roots in Keynsian economics, the concept can be usefully applied in this instance to indicate that small changes in one aspect of scholarly communication can result in much larger outcomes (see Chaos theory in section 6.4.5). Combining a series of small changes to variables, as with the 'perfect storm' factors (see sections 5.9 and 6.4), can result in a disruption to the traditional way of doing business. This is a central message from this thesis.

Summary

Many pundits claim that the traditional system is creaking. It is no longer fit for purpose (U.K. Select Committee, 2004; McGuigan and Russell, 2008). This is because of the number of inbuilt tensions within the industry sector. There are tensions:

- Between trust and fear within the changing knowledge environment
- Between collaboration or competition in the conduct of research
- Between privacy and sharing of information at the personal level
- Between transparency and control over research output
- Between elitism and democracy in governance
- Between profits and openness as business models
- Between traditionalists supporting existing system and innovators seeking something better

This is the context which faces STEM and its adoption of UKWs. It is from a dysfunctional, print-focused, base.

This chapter has also demonstrated the complications inherent within the digital scientific communication. Complex mixes of social concepts become the basis for the many changes taking place in STEM and surrounding industries. The overall conclusion is that financial barriers are not the sole reason why STEM publishing is having difficulty in adjusting to the digital environment, nor why the wider knowledge worker sector has remained on the sidelines. The fruits of research can be communicated to the wider audience in other, better ways, than relying on just the book/journal formats.

Expanding the publishing frontiers in terms of format availability would do much to break down the monolithic business model of subscriptions/licences also allow UKWs to be embraced within science in a more participatory role. In so doing the balance between supply of and demand for STEM information can lead to healthier business models being applied. This is crucial - to ensure that supply and demand forces are similar and participatory, less disparate and confrontational, in a new STEM environment.

The implications which change is having on existing and potential future STEM publishing formats is assessed in the next sections..

6.5. THE SCIENTIFIC JOURNAL

Methodology

This section of the thesis relies on books describing the process of journal publishing by industry experts such as Michael Mabe, Gillian Page, Sally Morris, Robert Campbell, Mark Ware and others from the STEM publishing industry. They provide descriptions of the editorial and production processes which are involved in bringing quality journals to market. Their focus has been on the mechanics of journal operation. Based on their writings the methodology adopted for this section has been to build on their work to indicate what the journal - as a communicator of scientific research outputs - may morph into as the 'perfect storm' forces come into play.

6.5.1. Functions of the STEM Journal

Over centuries the scientific journal has become the mainstay for communicating quality-controlled results within the research community. Journals performed four key functions which led to their dominance (section 1.2.5 under Definitions, and (Mabe, 2008)).

In a print-only world and in the early days of digitisation these functions were what the research community wanted. But as the Internet, the web, and digital support services became powerful, the relevance of some of these core functions are being tested.

Fast communication of the latest research data is important in a volatile scientific environment. The traditional printed journal does not do this readily. By focusing on creating a quality product (the article's Version of Record) through the certification process (refereeing), in-house desk-editorial corrections, and physical printing, a time-lag is built into the publication of the article in a print or e-journal of several months, in some cases years.

This is not what modern science needs, nor what researchers who have been interviewed by this author want (see Methodology section (meetings) and Appendix on Case Study). Alternative mechanisms for communicating the latest research output have emerged. New communicating formats, using social media and social networking, workflow procedures, collaboratories, datasets, 'mash ups', etc, have proven to be more in keeping with the digital capabilities and infrastructure within which authors/researchers are now operating.

The refereeing system in particular has come under scrutiny. In the print world, blind refereeing of a manuscript by at least two knowledgeable experts became the basis for ensuring that quality was maintained (Ware, 2005). Despite a number of well-documented individual failings and frauds, the refereeing system worked well. But in practice the conventional refereeing and sifting processes within STEM is slow, ponderous and dependent on the goodwill of a small group of referees (Ware, 2005). New online interactive and transparent systems for validating research have emerged. Whilst still relying on an assessment by one's peers, online refereeing including pre- and post- publication assessments have been tested.

The journal still has a role to play, but its main role is that of giving recognition and authority to the author of the article. Having an article published in a reputable journal the author can use the publication details to gain peer recognition, tenure, career enhancement, additional funding as part of their CV (curriculum vitae) submissions. All these are essential functions, but not critical for end users and knowledge workers who are seeking to keep up-to-date with the latest research developments, particularly those at the fringes of the academic system.

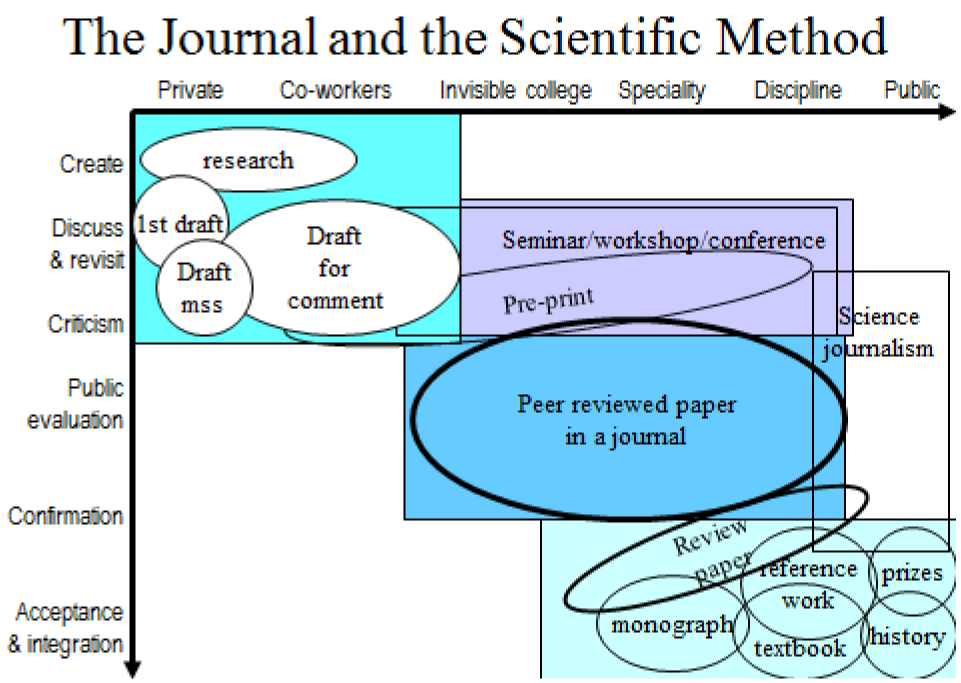
To quote an item from Velterop (an ex-traditional publisher) (Velterop, 2012).

> "We use journals not for conveying information, but for protecting scientific reputations and for fostering career prospects....... Hanging on to the old (subscriptions) in order to achieve the new (open access) may have been considered a suitable strategy ten years ago, but what it delivers is at best a form of open access that's likely to be merely 'ocular access' and of limited use to modern science, in contrast to the benefits that come with a radical change to full open access (no rights limitations, commercial or technical), not just to the equivalent of text on paper, but to all the potential that can be released from text, tables, graphs and images in electronic format."`

Velterop's qualifications for making statements about the future for STEM publishing come from his senior management experiences within Elsevier, Academic Press, BioMed Central and as developer of new STEM initiatives in the digital world.

The role of the journal is made more complex as a result of the many spin-off services which have emerged. The following chart developed by Michael Mabe, CEO of the International Association of STM Publishers, shows the relationship between the various formats as part of the scientific method for undertaking and disseminating scientific research.

Graph 6.13. The Journal and the Scientific Method



Source: Personal communication from Michael Mabe (CEO, Int. STM Association)

A further issue which challenges the role of the scientific journal is that of ‘negative results’. It is as useful to publish the results of research which fails to prove a point as it is to publish results which are supportive. Negative results enable time and resources to be saved by not following others down the same unsuccessful route. Publishing ‘negative results’ could be considered something of a failure, and as such researchers may be unwilling to lend their name to the results. Negative results now account for only 14% of published papers, down from 30% in 1990 according to a report in *The Economist* of 19 October 2013 (Economist, 2013). The stigma from being seen to be involved with research having negative outcome would appear to restrict openess.

Similarly, complaints have been made in the pharmaceutical sector that published research cannot always be replicated. Again, *The Economist* reports that biotechnology venture capitalists find that half the papers they analysed are unrepeatable. Amgen found that they could only reproduce 6 of the 53 ‘landmark’ studies in cancer, and Bayer found that they could only repeat 17 of 67 similarly important papers (Economist, 2013).

Experts from the library sector have also suggested that STEM journal publishing faces problems. A serial ‘subscription’ is in library terms a "publication that is intended to be continued indefinitely". For example, when a library subscribes to a journal, it is saying to the publisher "I'll pay you up front to send me all the articles published in a Journal X for a year, regardless of how many of the articles turn out to be of any actual use or interest to my patrons" (Anderson, R. 2013a). In the print environment the librarian had no choice but to buy articles that way, but in an online environment that level of built in waste is no longer necessary, and the library’s shrinking budgets are making it much harder to justify. It makes more sense to pay only for those items that are actually wanted and get used (Anderson R. 2013a).

Other pundits claim we are operating in an economy that has been shaped by the inefficiencies of the print environment. In one study the authors noted that “as many as 50% of papers are never read by anyone other than their authors, referees and journal editors.” It also claimed that 90% of papers published are never cited (Eveleth, 2014). There is a long tail in articles which are read infrequently. According to a leading US librarian (Anderson R, 2011), the long-term solution will not involve libraries paying for articles their patrons do not want, because the money to do this is no longer available (see section 6.3.5).

From the researcher's perspective there are a number of needs and motives which drive them towards becoming 'digital natives'. These include:

* To communicate with peers
* To be effective in undertaking research itself
* To socialise with researchers and others social groups
* To share the results of their efforts
* To build online communities of those with similar interests (see 6.6.2)
* To cooperate and partner with others
* To compete effectively in chosen area of research
* To become involved in crowd sourcing

(Source: Based on 'What Connected Humans Do', Susskind and Susskind, 2015 p 176)

From the above list the scientific journal offers few tangible advantages. Social media provides more useful platforms to capitalise on the informality and topicality which the exchange of research information in a digital world emphasises. These issues question the value of the research journal and the article as carriers of research results. As such they have implications on the new forms of information dissemination which may emerge, and how these may meet the information needs of the wider knowledge worker communities.

6.5.2. Alternatives to the STEM journal

As reported by Velterop (Velterop, 2012) in a blog in which he describes the role of the journal:

> "Very few journals are indeed 'journals' (in the sense of presenting 'daily' updates on the state of knowledge), except perhaps the likes of PLOS One and arXiv. So what we traditionally think of as journals have had their heyday. They functioned as an organising mechanism in the time that that was useful and necessary. That function has been taken over, and become far more sophisticated, by computer and web technology. That doesn't mean journals, as an organising concept, will disappear any time soon. I give them a few decades at least.
>
> I see articles also change in the way they are being used and perceived. They will more and more be 'the record' and less and less a means of communication. One reason is the 'overwhelm' of literature (see e.g. Fraser & Dunstan, on the

impossibility of being expert, BMJ 2010, http://www.bmj.com/content/341/bmj.c6815). 'Reading' in order to 'ingest' knowledge will be replaced by large-scale machine-assisted analysis of, and reasoning with, data and assertions found in the literature. Organisation of the literature in the current prolific number of journals — and the concomitant fragmentation it entails — will be more of a hindrance than a help.

Initiatives such as nanopublications (http://nanopub.org) and, in the field of pharmacology, OpenPHACTS (http://www.openphacts.org), are the harbingers of change."

New discovery tools, especially gateway services such as *Google Scholar, PubMed, Scirus* and the *Web of Science*, have made research literature more visible to more people more conveniently than ever before, but discovery and access is not the same. Researchers vented frustration over the limited range of journal titles available to them at their institution in the free text comments section in the CIBER 'Gaps and Barriers' survey (Rowlands and Nicholas, 2011). Many respondents were especially resentful when they found something that looked useful but for which they encountered a pay wall.

A key issue here is the tension between the `article economy' (what readers want) and the `journal economy' (the dominant business model for information supply in the form of subscriptions or site licences). The provision of simple (preferably free or inexpensive) mechanisms to deliver information at the article rather than journal level would extend the reach of research.

Blogs, wikis, moderated listservs, blogtalkradio, online seminars and webinars have emerged as exemplars of the new grass roots of information creation, thriving in open networking and democracy which the Internet has brought about, and are available for free and have extensive reach.

This suggests a new form of communication which could become the cornerstone of STEM, a communication system which is referred to as social publishing, based around Web 2.0 or even Web 3.0. In the meantime there are new alternatives in the pipeline. Bahrend Mons, Associate Professor at Rotterdam University, was instrumental in developing Knewco, a company which focused on disseminating 'nuggets' of biomedical information rather than full text describing research results, through adoption of Knowlet technology and the semantic web. It morphed from a scientific concept into a commercial operation in 2011 (and renamed itself as Personalized Media Communications) to develop personalised content recommendations and ads to readers. It has moved the goalposts away from journals/articles to other artefacts which meet researchers' information needs. This is one of a number of new STEM information services developed by and for researchers in the field.

Padley, CEO of Semantico, gave a wake-up call for 'what the article of the future is really about' (Padley, 2014). He suggested that if we were called on to design the ecosystem for scholarly communication today it would not look like it is now. He pointed out that print does have permanence, but such permanence is not necessarily what science needs. Features which should be designed into the 'article of the future' include the ability to change the article and not to lock it into the past. It needs to be interactive and updateable. It also needs to be executable — so that it leads through links into other sources and media. As researchers interact directly with each other's data it becomes possible for them not just to publish science online but actually create new science online.

Padley also thinks the article of the future should be reproducible. This means providing access not only to the raw data but to the software with which to manipulate the data.

> "This takes us a long way away from a world where recognition of academic results is more or less dependent on text …. contained in a document. However, for many publishers that mind-set is proving hard to change" (Padley, 2014).

A further extension of this is text and data mining (TDM) — if this takes hold does it mean that in future anyone will still want to actually read papers in the traditional way?

These isolated viewpoints need to be set against the panoply of other processes which relate to and impact on published research results. Several of these have been embraced by a wider society, and open up the potential for UKWs to become more involved in scientific research in future.

6.5.3. Alternatives to the journal article

Individual article supply, such as through document delivery services, has been a feature of STEM publishing for decades. Pioneered by what became known as the British Library Document Supply Centre in Boston Spa, Yorkshire, it enabled the purchase of individual articles. Other document delivery centres were established, both public and private funded, in other countries. However, they were controversial as far as STEM publishers were concerned. There was a fear that document delivery would undermine the sale of the subscription as libraries sought to provide relevance to their collections instead of accumulating material (Brown D, 2004). This was never proven despite a number of studies undertaken at the time (Artemis, ADONIS, OASIS).

During the 1990's and 2000's, the sale of articles through docdel (document delivery) services began to decline, with the unit sales from the BLDSC falling from 4 million per annum in the mid 1990's to 1 million in the late 2000's. Alternative options have emerged to usurp what many had claimed was an 'article economy' (Brown D, 2003).

Independently from this trend, the Association of Research Libraries (ARL, 2008) commissioned the Ithica organisation in the USA to investigate new formats which were becoming available and being used by scholars to communicate research results. Their report, "Current models of digital scientific communication", was published in November 2008. It highlighted that there was a number of non-traditional ways to disseminate scientific information, and whilst still peripheral in most subject areas - with the mainstream refereed journal as the accepted mode of communication - there were nevertheless subtle changes taking place.

The ARL/Ithica survey identified eight main types of digital scientific resources available at the time. These were:

- E-journals
  - This includes e-journals which allow immediate access to newly published articles
  - Some e-journals included multimedia, data visualisations, large datasets (such as JoVE: Journal of Visualized Experiments)
- Reviews

- Though highly rated as a service it does take a long time to write and edit each review so timeliness can be an issue
- Mainly of appeal in the humanities

- Preprints
  - Two key e-print resources were described including arXiv (physics) and Social Science Research Network (SSRN)
- Encyclopaedias and other reference works
  - Includes Encyclopedia of Life which encourages contributions from the lay public, although subsequent vetting is necessary
- Data
  - The Protein Data Bank was given as an example of mass participation in creating a global digital data resource
- Blogs
  - Blogs were seen as updated versions of the traditional listservs. Unlike discussion lists, blogs are more tightly controlled on who are allowed to participate
  - Of value in that it gives frequent updates of researchers' opinions and early thoughts rather than just facts which might have passed their sell-by dates.
  - However, blogs only represent interim stages, not the final results
- Hubs and Portals
  - Combines a number of formats within a single portal
- Discussions forums
  - Listservs, message boards, etc, are still used heavily in many disciplines
  - Not used to work through ideas, however, more as a broadcast medium for research updates

The above are not exclusive. They have some aspects of sifting or peer review built into their services. It was apparent to the authors of the study that quality control was an essential feature of scholarship.

The report was completed over seven years ago. It explains why the more 'communicative' forms are not included in the list – services such as *Youtube, Facebook, Twitter, Linkedin*, *WhatsApp,* etc – all of which could become part of the scientific communication system but not necessarily involved in developing the final record of scientific progress. Also excluded from the list were aggregations of links to other sites, software, digital copies of print content, industry newsletter and teaching-focused resources. Nor was Wikipedia which was seen more as a consumer-focused service.

The point in highlighting these new digital resources is that the unaffiliated (UKWs) have opportunities to take participate in such new ventures, more so than they had under the ‘elitist’ journal publication system. It gives the unaffiliated scope to sit at the same table as their academic peers in creating and developing products/services. It is an example of the Internet supporting more ‘democracy’ within the scientific information system.

6.6. FUTURE STEM COMMUNICATION TRENDS

Methodology

There is a future-focus in this section of the thesis. Though not adopting a formal Delphic approach it does speculate on alternatives to the journal and the research article as carriers of STEM research results as reflected in the published writings of experts. Such speculation, by the nature of the topic being forecast, currently lacks supporting evidence and is subjective. It is based on opinion and experience rather than facts and data.

Desk research is the basis for the data collection, though meetings were held with consultants and representatives from the publishing sector to test out some of the commentators’ speculations made in the literature.

There are several thematic areas with a fluid time horizon for implementation ranging from the near future (mobile and social technologies) to over ten years (artificial intelligence, cognitive developments, quantum computing and automation of knowledge). Each brings alternative carriers for research results onto the scene, and these differ from those offered by conventional books and journals. Each has implications on how publishers and libraries come to terms with future developments (Brown D & R Boulderstone, 2008).

However, the past few decades give grounds for caution in anticipating the direction which new information technologies will take. The launch by IBM of the PC in 1981 was entirely unexpected; by the same token the Web’s arrival in the early 1990’s was unanticipated; social media arrived on the scene more recently which has had a radical impact. None of these could have been forecast. By the same token it is impossible to anticipate what will capture the imagination of the STEM sector in the next five to ten years. Something equally profound may emerge which may not be a linear progression from what we currently have as a research dissemination system. Several indicators of such change could be the following. None are definitive, but the exercise of pursuing possible lines of future technological development affecting STEM is preferable to assuming there will be no change.

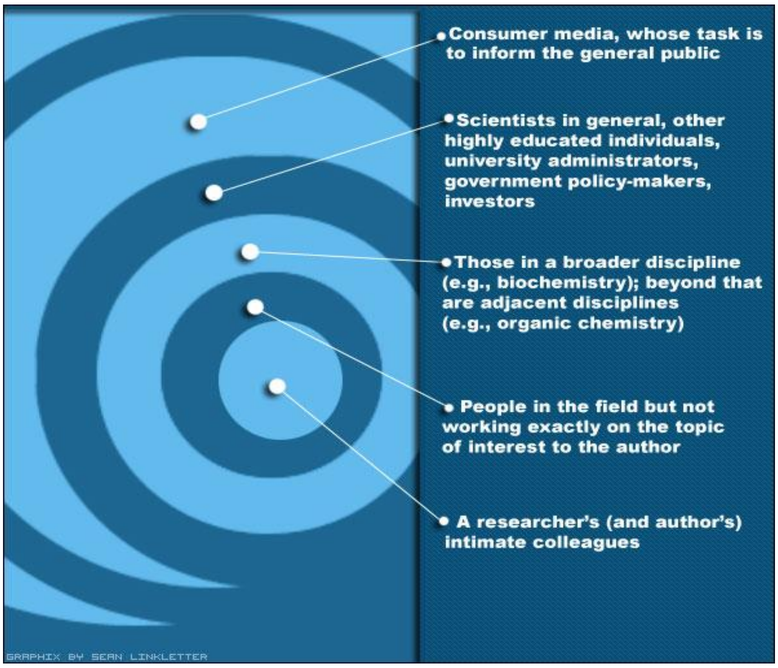
6.6.1. Repackaged STEM publications

An industry commentator based in the USA – Joseph Esposito – has applied the Nautilus concept to the drift outwards in information demand and supply. In so doing he suggests that there is a different publishing model required to reach those knowledge workers further out from the original source of content creation (Esposito, 2007). From the requirement for rapid access to primary research findings the nature of demand may change towards secondary (abstracts and metadata) and tertiary (review, reference) material the further out one goes from the centre of scientific research. The implication is that there is a new opportunity which could open up to satisfy the demands of 'the long tail'. This opportunity is more tertiary, informed and educational in nature than high level primary scientific reporting for academic researchers as in research journals and datasets.

According to Esposito it is possible to envisage scientific communications as a spiral; the inner spiral represents the researcher's closest colleagues; the next spiral outwards is for people in the field but not working on the topic of interest to the author; one more spiral and there is the broader discipline; beyond that are adjacent disciplines; until one moves to scientists in general, highly educated laypersons, university administrators, government policy-makers, investors, and ultimately to the outer spirals, where there is the general public and consumer media.

Graph 6.14.

Nautilus model of scientific communications



Source: Esposito, 2007

Something may be lost in translation as research information moves outward from the core research. Without accuracy in 'translations,' the loss would be great as errors in interpretation could develop. In effect, to translate a research article from its technical register into everyday English would (depending on the approach taken) make it more ambiguous or more verbose and therefore worse than the original article from the perspective of the primary audience. This is a stylistic issue which needs to be addressed (see section 5.8.2 on Science and the Media).

At each spiral away from the centre, the role of the publisher potentially grows. Esposito offers the scenario that publishing and open journalism could take on not just the primary role of certifying the original research result, but also a tertiary role of interpretation for much wider audiences – to overcome ambiguity and verbosity. UKWs would be major beneficiaries in this scenario.

Esposito believes that the future of communications needs to be based on the infrastructure of consumerism (Esposito, 2010; 2012b). "This is because in a networked world the *number of nodes connected to a network matter [Metcalf's Law] and the consumer market has the big numbers". The issue which needs addressing is how to layer academic needs and interests onto the consumer market's platforms, using modern tools such as Google, iPhone, *Facebook, Twitter, FigShare* and *LinkedIn*.

Allington makes the point that it is not part of a researcher's mission to be effective in public education of STEM (Allington, 2013). They are different functions, with high level description of research results not sitting well with a layman description of the same results. The nearest Allington comes to suggesting that the researcher serves both audiences is his proposal that Research Councils in the UK revamp their web sites to include mandated synopses or executive summaries of the funded projects provided by the researcher, both before and on completion of their work (see Allington in section 4.1.2.5).

There are also other services which tap into the need to provide 'translation' of research results to reach a wider market. A UK start-up entitled Kudos, established in 2012/13 by a group of ex-STEM publishers, provides authors and publishers with ways to reach the public audience. This because Kudos' initial investigations indicated that 84% of authors contacted felt more could be done to 'raise the visibility, impact and usage of their work' (Smith D, 2013). In recognition of their approach, ALPSP voted Kudos as having the most innovative industry product in 2015.

Enabling more people to appreciate the implications arising from a successful research project in a way that is understandable would go a long way to meeting needs of UKWs and also ensuring a healthier STEM information system. However, the practical aspect of seeing that both 'core' and 'long tail' parts of the science community are delivered reports in a useful way may only be possible with the introduction of more customised/profiled information delivery systems (RSS, Alerts), and a greater range of publication formats (hubs or portals).

6.6.2. Online Communities

In both the publishing and library worlds there has been experiments by information providers to become mediators in scholarly interaction/discourse in a digital world. However, it has been the convention for publishers to conceal what they are doing in this area for competitive reasons. The indications are that with the exception of the large commercial and learned society publishers such experimentation has been limited.

It is conceivable that publishers' strong positions in professional niches might give them opportunity to exploit new market conditions by using social media. This could be through partnerships with professional societies but discussions with such associations have not shown much activity.

There are a few examples of online communities in non-research focused sectors of society. In medicine there is PatientsLikeMe; in education there is Edmondo; in divinity there is BeliefNet; in journalism there is GlobalVoices; in consultancy there is OpenIDEO; in the taxation area there is AnswerXchange and in architecture there is WikiHouse (source: Susskind, 2015 p224).

Aggregations of different types of information – formal printed articles, moderated bulletin boards, social media, data compilations, news, appointments, legal issues – constitute the definition and content for online communities, hubs or portals. Most publisher-generated blogs take the approach of informing the community what they are doing, rather than stimulating interaction and community collaboration. Wiley and Elsevier are known to be experimenting with community building often with groups of journals but it is difficult to find anything substantive about these experiments. The correct formula has yet to be discovered and shared. Some of these issues raised with researchers are discussed in the Case Study in the Appendix 3b.

6.6.3. Artificial Intelligence and Cognitive Computing

Originally referred to as artificial intelligence, researchers began to use the term cognitive computing in the 1990s to indicate that science was designed to teach computers to think like a human, rather than building and improving on an established system. Cognitive computing refers to the development of computer systems together with biological input modelled after the human brain. As a technology/process it has implications on how the research community, including knowledge workers, interacts with computers in future.

Examples of the route which such intelligent application of technology is taking includes IBM's Watson computer. IBM Watson is a technology platform that uses natural language processing and machine learning to reveal insights from large amounts of unstructured data (see www.ibm.com/WatsonAnalytics). The important attribute of Watson is not so much the way it out-performs individual specialists in solving problems but rather the way it does it differently from the human approach. It provides answers through sheer weight of analysis of vast amounts of historical information. It leads on to research in such areas as quantum computing, offering new and even more powerful approaches to the analysis of large stores of data. It offers potential to effect 'mash-ups' - integrating datasets from different sources to achieve even more innovative approaches to (identifying and) resolving problems.

In some areas technology will outperform the human innovator. However, if autonomous machines are to be set loose, moral codes will need to be translated into software codes. They will need to reflect human emotions such as creativity, affection and regret. As a society we could rue the fact that artificial intelligence/cognitive computing could be given the ability to make decisions which impact on the general moral code. As referred by Carr (in Carr, 2016 p187), "The age of ethical systems is upon us".

In essence, such developments if integrated into a future STEM system, will change the landscape for publishers, librarians, researchers and knowledge workers. Books and journals provide less relevance, and manipulation as Big Data and its manipulation takes over. However, there is no consistency on what form this trend in Big Data manipulation will take. Data manipulation services are the tools; it will require innovators and entrepreneurs to rework these tools into useful artificial intelligent (AI) services. The likelihood is that each subject area, discipline or large research project will develop their own portfolio of data services, cherry-picking the most appropriate from the range of new technology available.

The result is that a pedestrian approach to scientific research in future may be overtaken by a close human/computer encounter which, besides improving the research process itself, will generate innovative ways to share and disseminate output from such research which could be more open, less academia-focused, than in the past.

6.6.4. New approaches to scientific communication

There are a few common themes in the way STEM researchers adapt to the new informatics climate. Comments in a blog by Professor Jeffery, Director International Relations, STFC, focuses on the way technology and usage are beginning to interact on the researcher.

> "Technologically the user interface level is likely to be semantic web/linked open data driven from below by a formal information system with very rich metadata and services linked as business processes for research discovery, analysis, manipulation, mining and communication from the researcher 'workbench'. Interaction by speech and gesture rather than mouse and keyboard will become the norm". (Jeffrey, 2012).

Text and data mining, enabling new ideas and relationships to be found from access to research material on different platforms, is critical in some biomedical areas in particular. Collaboratories, involving teams from across continents sharing and exchanging research results are springing up in many natural and life science areas.

The social dynamics within the scientific community was summarised by Professor Jeffery (Jeffrey, 2012), again on the GOAL list serv:

> "A new generation of researchers is entering the system. They live in the Web 2.0 generation now and will evolve with whatever comes next. They are still impressed by what can be done with http, html/xml and urls; they don't imagine a world without them. They will expect immediate interaction with hyperlinked multimedia. They have little or no respect for legalities or long-established traditions. Glory is counted by 'likes' or 'friends' and – as an aside – is more quantitative and reproducible than existing 'glory' metrics (especially the dreaded impact factors and related indices). They may want peer review as it is now but seem to manage the rest of their lives using online recommendations from peers they either know or respect or both. They will certainly expect to live in a research world with wider conversation including social/economic/political commentators which links with the 'outputs - outcomes – impact' agenda".

A similar point was made in the book edited by Bartling & Friesike (Bartling et al, 2014):

> "Researchers all over the world use modern communication tools such as social networks, blogs, or *Wikipedia* to enhance their scientific expertise, meet experts, and discuss ideas with people that face similar challenges. They do not abandon

> classical means of scientific communication such as publications or conferences, but rather they complement them. Today we can see that these novel communication methods are becoming more and more established in the lives of researchers; we argue that they may become a significant part of the future of research."

As reported by Dr Peter Murray-Rust (Cambridge University) on the moderated GOAL bulletin board on 10 August 2012, the 250,000 people who helped create the Open Street Map project and get it accepted as being among the highest quality and most useful cartographic service – the contributors did not come from old-school cartographers.

> "They came from all walks of life, including cyclists and ramblers. Wikipedia didn't come from converted academics, it came from people outside academia and encyclopedias. Academia (with a very few exceptions) howled it down and it has succeeded in spite of this".
>
> Dr Peter Murray-Rust, GOAL, August 2012

Studies, some funded by government agencies, have investigated alternative methods for scientific communication. The UK Finch report (RIN, 2012) addressed conflicting opinions about ways to disseminate research findings. With hindsight it was probably a mistake for the membership of the Finch Study group to be dominated by organisations from the existing supply chain – funders, publishers and librarians - who have an interest in seeing minimal disturbance occurring to the status quo (albeit allowing for some marginal changes). More radical would have been to have had the committee dominated by researchers working at the many frontiers of science, those with a view on strategic trends in science and its communication needs. A Delphic group. But Finch nevertheless provided a catalyst for the subsequent debate about appropriate business models for journal publishing in the emerging digital world.

It is not correct to claim that commercial journal publishers have neglected experimentation with new forms of STEM publishing. Elsevier, with its substantial financial resources, has committed to a number of research projects to define a future for itself. One of these was the so-called 'Article of the Future' which included new ways of presenting and navigating through articles, which are now being included in several Elsevier titles. The project design was based on interviews with some 800 researchers (Zudilova-Seinstra, 2013) and made available through Elsevier's Content Innovation and Science Direct programmes.

From the range of alternative STEM publishing options for the future, two are highlighted as offering particular interest in bringing technology to the aid of improved STEM access for UKWs and the knowledge worker industry as a whole.

6.6.4.1. Portals and Hubs

The first is hubs or portals. In effect digital portals include a range of information services targeted at the needs of a defined community and build on the Online Communities. Hubs or portals can include access to e-journals, reviews, e-prints, conference papers, grey literature, blogs and/or newsletters, all with the aim of consolidating relevant information targeted at a researcher's profile. Decisions on what should be included in the portal would lie with a 'gatekeeper' within the information service, a maven who would be fully aware of all the issues which the targeted community could face and the information content they would need.

An example of a 'one-stop shop', hub or portal includes IBMS BoneKEy, a web portal of the International Bone and Mineral Society, and also Information for Practice which is directed towards social work and practice. Another portal is the Alzheimer Research Forum.

However, they are costly to create and maintain, and a variety of business models need exploring to ensure their viability. Advertising and corporate sponsorship may be involved.

6.6.4.2. SDIs and Alerts

A second STEM service is derived from a traditional SDI (selective dissemination of information) concept which was popular in the early days of digital publishing. It has since been revamped as Alerts and RSS services (Really Simple Syndication). It has potential for improved linking of supply with demand for STEM research output.

This raises scope for business models which are granular in scope to enable the interest profile of an individual knowledge worker to be matched against the content of published items coming on stream. The profile of the user is related to content's metadata to trigger delivery. Such an SDI scheme would offer advantages, such as relevance and timeliness, over the current scheme of broadcast publishing.

The SDI profiled system would predict what items may be relevant to the target audience, based on a profile or on what the individual had expressed an interest in recent past, and proactively supply information in advance. It is analogous to the system which Amazon uses to stimulate book sales – to use records of past purchases to recommend relevant and related items of future interest. To follow the digital trail left by an online researcher, and to match this trail with metadata associated with incoming items/documents.

This single integrated approach, covering the research information needs from soup to nuts, from a wide range of sources rather than focused on one (journals), is in keeping with the successful business strategy adopted by industry innovators such as Steve Jobs in his development of Apple ("Steve Jobs", by Walter Isaacson, 2011). Making sure that all information bases are covered - Macintosh, iPad, iPod, iPhone and including iTunes store - through one easily accessible system, meant that Jobs was able to out-manoeuvre and out-compete with other key players at the time. "A magical walled garden where hardware, software, [content], and peripheral devices worked well together to create a great 'user experience" (Isaacson, 2011). The proposed linked, integrated STEM system, can be reflected in the SDI and portal approach for researchers outlined above.

There are other approaches to delivering STEM results in an efficient way and which could become an agenda for a Delphic study organised in a sophisticated and professional way. However, this comes with a health warning. According to Steve Jobs (Isaacson, 2011) "Some people say "Give the customers what they want". But that's not my approach. Our job [at Apple] is to figure out what they are going to want before they do. I think Henry Ford once said, "if I'd asked customers what they wanted they would have told me "a faster horse". Present-day researchers may answer more and better journals, which would not solve the STEM dysfunctionality issue. A Delphic approach would need a different mindset to that of operational-expansion or business exploitation which characterises many existing organisations.

6.7. RESULTS FROM RESEARCH AND ANALYSIS

Methodology

Several approaches were taken to collect information about the current state of the STEM publishing industry. This included the comments reported on in section 4.1.2. The procedure was to combine the results from different sources and to use this as a basis for analysing the health and value of the STEM information system as it currently exists**.**

There is subjectivity in making such assessments but they are based on best evidence available from experienced industry watchers, sociologists, neurologists, technologists and business consultants. Critical analysis of the source items was made, and judgements given on whether they matched with other items describing strategic trends in STEM.

6.7.1. Results from meetings held with stakeholders

Twenty one-to-one meetings were held as part of this thesis during the period September 2009 to June 2014. The results from several meetings related to UKW issues were described in the previous chapter (see 5.14.3). The following relate to meetings/interviews held relating specifically to STEM developments.

- Discussions with members from the commercial side of STEM publishing showed that immediate profitability and cost controls were taking precedence over investment in strategic planning and developing appropriate visions for the future. As an example of the problems faced in getting buy-in from STEM publishers into the thesis, the following comments were offered by one of the contacts:

> "That is rather disappointing. There does seem to be a trend in the larger publishers at the moment to be doing the following:
> * Reorganising structure – particularly combining book and journal divisions
> * Developing much stronger links between geographical divisions
> * Major IT systems overhauls

* Investing in new technology tools, particularly those that communicate directly with authors and readers

So it may be that budgets are already allocated to quite large projects”. (Source: Laura Cox, director of Ringgold)

- Operationally-focused policies among STEM publishers can be attributed to the ownership structures of these companies, where external investors (particularly venture capitalists) determine that short term profitability is more important than having certainty about business prospects in five years' time. Companies such as Nature Publishing Group (one of whose directors was interviewed for this thesis) have shown a more adventurous approach but their recent merger with Springer S&BM raises uncertain implications for their future strategies. In general, STEM publishers seem to be assuming that the good times will continue.

- New approaches are coming from innovative companies outside the traditional STEM publishing sector. One of these – DeepDyve – is looked at as a case study in the Appendix. Others such as Mendeley come out of the research environment where the researchers are aware of different needs for information services and design and implement them accordingly. Knovel has pioneered a new approach to information packaging for engineers. (These companies are the target for acquisitions by the large commercial journal publishers).

- Librarians are also caught in the headlights of rapid technical and social change, and as meetings with staff at the British Library has shown, they are also subject to external pressures. Some of these come from the STEM publishing sector, with whom there has been an acrimonious relationship on issues such as document charges, digitisation and legal deposit. This against a funding restriction which faces all libraries in trying to keep pace with the growth of published output and escalation in publisher-set prices (see Dysfunctional STEM section of the thesis with item on ‘serials crisis’, section 6.3.5).

- The issue of open access has been discussed with the Head of Digital Services (and colleague) at Wellcome Trust – this funding organisation has taken the lead in extending mandates for open access provision to its funded research output, and to enabling text and data mining to take place

6.7.2. Results from online communications

Email contact was made with a cross section of representatives among researchers and stakeholders in the UK.

Publishers

> Contact was made with senior management from the larger commercial journal publishers to reinforce the face-to-face discussions held with leading society publishers in the UK. The conclusion was that more concern about the strategic directions were voiced by the larger publishers than was apparent during meetings with the smaller society publishers, though this level of concern did not translate into active cooperative programmes of futuristic scenario building.

Librarians

- The Library and Information Services Manager, Standards, Knowledge and Information Services, Royal College of Nursing provided data on an internal study of nurses' information needs (Royal College of Nursing, 2013). The contact also provided a list of internal RCN (Grey literature) publications which relate to this project.
- Another library contact undertook a survey of libraries within learned societies (Linacre, 2009) and she subsequently shared her unpublished findings.

Intermediaries

- The director of Ringgold provided names and contact details of a dozen representatives from UK-based learned societies all of whom were contacted for the study. Few responded which further supports the contention that there is a large degree of conservatism which dominates strategic thinking within (small) learned society publishers in particular.

Consultants

- *Skype* contact was made with consultant Joseph Esposito as a follow-up to our face-to-face meeting in California to check on his latest thinking and to ensure agreement to have his thoughts included in the thesis.

Researchers

- Telephone contact was made with UK researchers during early years of this project. The results are summarised in the Methodology section and in the case study included as Appendix 3b.

6.7.3. Results from external market research company

Outsell is a US-based consultancy and market research organisation which gained a UK presence through its acquisition of Electronic Publishing Services (EPS) Ltd in August 2006. Outsell monitors overall information industry developments, and has pioneered quantification in many sectors of the global publishing industry. The former director of EPS and now consultant to Outsell, was also interviewed during the course of this study.

Outsell reports demonstrate the range of entities within the Information Economy. Scientific publishing is one small part of the overall information industry, but also one of the more profitable parts. According to Outsell's '*2009 Information Industry Market Size, Share and Forecast Report'*, the main elements of the Information Industry consisted of:

Table 6.7. Information Industry Sectors

Industry sector	**Estimated Revenues in 2009 (in $millions)**	**Estimated Growth or Decline over 2008**
Professional Information Services		
Scientific, Technical & Medical	$23,977	+1.2%
Search, Aggregation, Syndication	$48.774	+1.1%
Legal, Tax & Regulatory	$15,061	+1.7%
Education & Training	$46,601	+3.0%
Trade Information Services		
B2B Trade Publishing	$3,824	-10.1%
Yellow Pages Directories	$32,312	-9.0%
Company Information	$18,436	-15.3%
Credit & Financial Information	$41,269	-2.0%
HR Information	$3,397	-18.0%
Market Research reports	$31,058	-6.2%
IT and Telecoms research	$2,747	-9.2%
Newspapers		
News providers	$99,875	-19.0%
Total Global Information Industry	$367, 154	-8.0%

Source: Outsell's Publishers and Information Providers Database, Outsell, 2009

The above table demonstrates that the Scientific, Technical and Medical Information sector represents a small share - approximately 6.5% - of the global information economy. The net effect is that STEM is considered a relative minion within the global information industry. This has helped protect it in the past from excessive public and media scrutiny.

Summary

An established statistical technique used to study a complex topic is a tripartite approach – combining the results from different sources of information. From integrating the separate sources listed in the previous chapter with the above sources, a picture is emerging for this MPhil project. The consensus is

(a) That STEM industry trends are obscured behind veils of corporate obscurity
(b) There are concerns that STEM is not fit for purpose in a digital age
(c) There is lack of leadership from existing stakeholders in creating or experimenting with new paradigms
(d) There is an elitism about the current system whereas a more open and democratic system would embrace the STEM information needs of the knowledge worker sector
(e) There is insufficient knowledge nor awareness of the needs and habits of knowledge workers and UKWs

These issues form the backdrop to the chapter entitled Discussion (chapter 8), and then Conclusions (chapter 9). Before that an assessment is made of one stakeholder - Learned Societies - which could offer a lead into creating a new paradigm for STEM whilst also meeting the needs of unaffiliated knowledge workers.

RESULTS - 3

UK LEARNED SOCIETIES

This thesis recommends that learned societies should play an important part in facilitating outreach to the UKW communities, subject to these sectors undergoing transformation to meet changing market needs.

The positive view is that there is a gap which learned societies could fill in the STEM area, relying on the strength of their relationship with a dedicated audience and underpinned by a social mission which is less confrontational than that which currently exists between the main STEM stakeholders (see chapter 6 - Dysfunctional STEM).

Methodology

The approach is a qualitative analysis based on desk research covering both relevant formal and informal publications. Both sources were analysed. In addition, using the responses received from interviews with representatives from several UK learned societies, one-to-one interviews fleshed out some additional details. Discourse analysis was applied subsequent to these meetings to ensure that hidden agendas did not influence the interpretations. These meetings focused on the learned society's current operations and strategic ambitions, and views expressed were from individuals close to the UK learned societies.

This analysis also involved analysing existing numerical data about learned societies – their numbers, memberships, publication programmes and operations. It also explored outsourcing journal publishing activities by several societies. Another focus was on new information dissemination services they might provide to their members which would offer membership benefits in future. These relied on interpretations based on meetings held and literature reviewed.

In addition, a study undertaken by Richard and Daniel Susskind and reported in their book "The Future of Professions" (Susskind, 2015) provided indications on future developments within the main UK professions. It was a visionary analysis based on their seven years of research into, and knowledge of, the law and financial professions in particular.

This combination of current operational evidence and future speculation represents the platform on which this chapter on learned societies is based. A picture emerges of a sector which has the potential to adapt its corporate mission to being in tune with the Internet's democratic features of openness and interactivity.

7.1. UK Learned Societies

The key point to make about learned societies is that they have the ability to select relevant information – in whatever format – for a target group whose information profile they know better than either commercial publishers or librarians. Publishers and librarians have generic approaches to information provision - learned societies are specific to a community whose interests they live with, understand and protect.

The conventional way for learned societies to support their publication programme is for members to pay annual membership fees. One membership benefit has been a free or subsidised subscription to the society's publications. Individuals who were not affiliated with the society could still get access to the publication, but they would have to subscribe at a higher commercial price. The resulting income provides support not only for the members' information programmes but also for supporting other society activities.

Learned societies are crucial in the sociology of science. The formation of a society is an important step in the recognition of a new discipline or profession. Societies can be general in nature, such as the American Association for the Advancement of Science (AAAS), specific to a given discipline, such as the Modern Language Association, or focused on an area of study, such as the American Association of Professors of Yiddish. They can also operate in a particular country often with local branches, or are international, such as the International Federation of Library Associations (IFLA) or the Regional Studies Association, in which case they often have national branches.

Affiliation to a learned society may be open to all, may require possession of an acceptable qualification, or may be an honour conferred through election. Their activities typically include holding regular conferences for the presentation of new research results and publishing or sponsoring academic journals in their discipline. Some also act as professional bodies, regulating activities of their members in the public interest (the 'grand bargain', see Susskind, 2015 p 21).

The number of society members can vary widely from a few specialists to tens of thousands of members. A compilation of approximately 17,000 UK-based learned societies and trade associations is published in *The CBD Directory of British Associations and Associations*, together with addresses, contact details and in many cases the number of individual members in the UK (CBD, 2009). A selection is given below. It is not a comprehensive list of scientific-related societies, but it indicates those which might have a requirement to support a broader network of potential users of STEM material.

Table 7.1. UK Learned Societies and their membership numbers
UK membership only

Association of Chartered Certified Accountants	58,000 members
Association of Optometrists	11,000 members
Authors Licensing and Collecting Society	15,000 members
Biochemical Society	6,000 members
British Association for Print and Communication	3,800 members
British Astronomical Association	3,500 members
British Medical Association	115,512 members
British Psychological Society	38,485 members
British Trust for Ornithology	9,000 members
Chartered Institute of Library & Information Profs	22,830 members
Council of British Archaeology	6,000 members
Dental Practitioners Association	3,000 members
Diabetes UK	180,000 members
Energy Institute	12,000 members
Federation of Small Businesses	215,000 members
Forensic Science Society	1,750 members
Friends of the Earth	100,000 members

Geographical Association	3,155 members
Historical Association	5,300 members
Institute of Biology	15,800 members
Institute of Biomedical Science	15,000 members
Institute of Ecology & Environmental Management	3,500 members
Institute of Food Science and Technology	2,221 members
Institute of Marine Engineering, Science & Technology	10,073 members
Institute of Mathematics & its Applications	4,400 members
Institute of Chemical Engineers	18,168 members
Institution of Civil Engineers	60,891 members
Institution of Engineering and Technology	150,000 members
Institution of Structural Engineers	16,300 members
Linnean Society of London	1,700 members
Marine Conservation Society	5,200 members
Mathematical Association	5,000 members
Mineralogical Society of GB& Ireland	900 members
Motor Neurone Disease Association	6,500 members
National Union of Teachers	250,000 members
Nautical Institute	6,500 members
Network of Government Library and Info Specialists	494 members
Operational Research Society	2,290 members
Patient Information Forum	778 members
PERA	500 members
Permaculture Association (Britain)	800 members
Philological Society	618 members
Physiological Society	2,000 members
Publishers Licensing Society	1,800 members
Royal Aeronautical Society	15,000 members
Royal Agricultural Society of England	5,935 members
Royal Anthropological Institute of GB & Ireland	1,000 members
Royal Archaeological Institute	1,700 members
Royal Astronomical Society	2,037 members
Royal College of General Practitioners	17,500 members
Royal College of Obstetricians and Gynaecologists	4,000 members

Royal College of Ophthalmologists	2,800 members
Royal Horticultural Society	335,000 members
Royal Institute of British Architects	30,000 members
The Royal Society	1,200 members
Royal Society of Chemistry	34,721 members
Royal Society of Edinburgh	1,200 members
Royal Society of Medicine	17,000 members
Scientific Exploration Society Ltd	400 members
Scientists for Global Responsibility	950 members
Scoliosis Association	3,000 members
Scottish Engineering	350 members
Scottish Motor Neurone Disease Association	800 members
Scottish Optoelectronics Association	50 members
Society of Applied Microbiology	1,300 members
Society of Authors	8,000 members
Society of Automotive Engineers	2,000 members
Society of British Neurological Surgeons	400 members
Society for Endocrinology	1,400 members
Society for Experimental Biology	1,350 members
Society of Food Hygiene and Technology	700 members
Society for General Microbiology	3,925 members
Society of Glass Technology	350 members
Society for Popular Astronomy	3,100 members
UK Clinical Pharmacy Association	2,000 members
UK Serials Group	600 members
Writers' Guild of GB	2,000 members

It is clear that there is a wide diversity of associations and learned societies in the UK catering for many specialised business and social interests.

7.2. Journals and professional societies

The number of subscribers to STEM journals for a selection from the above associations is in the range of 600-1,500 worldwide, similar to those of commercial journals. However, membership totals of the learned societies listed above average 24,000 members. This could give global figures for learned society membership of up to 300,000 (assuming UK's share is 6% of world totals). The distinction between current subscription levels of journals (up to 1.5k) compared with the potential readers among learned society members worldwide (up to 300k) indicates that a better STEM information system could reach large additional audiences even just within a professional society.

An association which acts on behalf of the publishing interests of learned and professional societies is based in the UK but has global aspirations. This is the Association of Learned and Professional Societies, or ALPSP. Some members have their own journal publishing units, others have devolved their publishing activities to commercial publishers in order to benefit from economies of scale. Examples of this range of alternatives can be seen in the following table which gives membership details and an indication of who was responsible for publishing their scientific journals in 2013/14.

Table 7.2. Publishing activities of ALPSP members (2013/4)

Learned society	Number of members	Publishing agency or partner
Association of Applied Biologists	800 members	Wiley
Biochemical Society	6,000 members	HighWire Press
BMJ Publishing Group	11,512 members	BMJ Publishing Ltd
British Ecological Society	?	Wiley Open
British Pharmacological Society	1,700 members	British Pharmacological Society
British Psychological Society	38,485 members	Wiley Online
British Society for Immunology	3,500 members	Wiley
British Society for Rheumatology	950 members	Oxford University Press
Company of Biologists	?	Company of Biologists
Geological Society	?	Geological Society Publishing House

Hydrographic Society	475 members	-
ICE Publishing	18,168 members	Institute of Chemical Engineering/Thomas Telford
Institute of Marine Engineering S&T	10,073 members	ImarEST
Institute of Mathematics and its Applications	4,400 members	Oxford University Press
Institute of Physics and Engineering in Medicine	?	IoPP/Elsevier/Informa
International Food Information Service	?	?
London Mathematical Society	1,700 members	Oxford Digital Archive
Mineralogical Society	900 members	Mineralogical Society
Nutrition Society	?	Cambridge University Press
Pharmaceutical Society	?	PJ Press/Royal Pharmaceutical Society
Physiological Society	2,000 members	Wiley
Royal Astronomical Society	2,037 members	Wiley
Royal College of General Practitioners	17,500 members	RCGP/World Wide Subscription Service
Royal College of Nursing	?	BMJ
Royal College of Obstetrics & Gynaecology	4,000 members	Wiley
Royal College of Physicians	18,900 members	Ingenta
Royal College of Psychiatrists	6,941 members	Maney Publishing
Royal College of Radiologists	5,820 members	Royal College of Radiologists
Royal College of Surgeons of England	?	Ingenta
Royal Geographical Society	?	Royal Geographical Society
Royal Society	1,200 members	HighWire Press
Royal Society of Chemistry	34,721 members	Royal Society Chemistry Publishing
Royal Society of Edinburgh	1,200 members	Royal Society Edinburgh Scotland Foundation
Royal Society of Medicine Press Ltd	17,000 members	Royal Society Medicine Press

Society for Editors and Proofreaders	1,315 members	Society of Editors and Proofreaders
Society for Endocrinology	1,400 members	Portland Press (Wiley)
Society for Experimental Biology	1,350 members	Oxford Journals
Society for General Microbiology	3,925 members	?
Society for Advancement of Management Studies	?	Wiley
Society for Underwater Technology	868 members	?
Society of Biology	?	Society of Biology
Society of Indexers	850 members	Society of Indexers
The Energy Institute	12,000 members	?
The Gemmological Association of Great Britain	?	?
The Institute and Faculty of Actuaries	?	?
The Institution of Engineering and Technology	150,000 members	Institute of Engineering and Technology
Zoological Society of London	?	Wiley

Source: Based on analysis of data on the ALPSP web site, www.alpsp.org

The business relationship between professional associations and commercial publishers is based on economies of scale. Commercial publishers are able to offer greater technical and economic support services (see section on economies of scale, 6.4.1.6). The economies are in the form of having effective technical platforms from which content can be delivered; more technical bells and whistles in the type of service offered to end users; greater global marketing and distribution arrangements particularly in rapidly developing far east markets; and the avoidance of internal bureaucracy which could lead to the learned society taking its eye off its main mission in monitoring its publication programme.

The rise of open access publishing (OA) in its various forms (see 6.2.5.1) and social media developments (section 5.12) changes the situation, and learned societies now have alternative ways of reaching out to both established and new members.

7.3. EDP Study on Learned Societies and Open Access

In 2013/14, EDP Open commissioned TBI Communications Ltd to evaluate learned societies in the US and UK and to determine what their views were about open access publishing. 33 responded to the survey (TBI Communications, 2014). Key results reported in the study included:

- Only half the societies responding were in favour of open access. There was a small number which were negative about the concept
- The majority of societies offered open access via Green routes in repositories.
- Hybrid article open access was offered by over three-quarters of societies
- Gold open access was offered by few of the societies
- Societies overwhelmingly agreed that open access will place some learned societies' journals in financial difficulty. This was particularly the feeling among those societies based in the US
- The most significant challenge relating to open access is the need to protect revenues
- Appropriate commercial strategies were ill-defined among two-thirds of the respondents
- Competing with specialist open access publishers was considered a challenge

How many scholarly societies publish OA journals? In a publication produced by a leading US advocate for open access – Peter Suber – in September 2013 he identified 832 societies publishing 780 full or non-hybrid OA journals (Suber, 2013). Of the 780 OA journals published by societies, a majority - 451 or 58% - charged no publication or submission fees.

Two-thirds of the societies in the EDP study were still seeking advice on how best to meet the open access challenge, and how to ensure compliance with funder mandates. They are hampered by lack of access to good information to help them make optimal decisions (TBI, 2014). It should be pointed out that the TBI report was based on 33 returns; Suber identified 832 open access societies alone. As such, the conclusions given by TBI were at best indicative.

7.4. Collaboration among learned societies

One way forward for learned societies is to collaborate on problems of mutual concern. For example, to share their publication support activities. The Society of Endocrinology has set up a separate company – bioscientifica.com – which is the commercial arm of the society and has as its mission to make profits. It reconciles the social aims of the society with its profit-seeking activities by ensuring that the profits are for the benefit of the society and not for external investors. According to the head of publishing at Bioscientifica, the society is like many others in the UK, too small to make much of an impact on the publishing industry on its own. There is strength which comes from collaboration (source: meeting with representative from Bioscientifica).

Bioscientifica has joined forces with other learned societies and university presses to use the same hardware platform developed by HighWire at Stanford University in the US. Not only is technical support provided to these societies, but also a common sales and marketing service is shared. Other similar collaborative efforts among the learned societies include BioOne and JSTOR, and the Association of Learned and Professional Society Publishers (ALPSP) has created its own version of the Big Deal to compete with commercial publishers.

The ALPSP association has a role to play in assisting its members. As reported by the chief executive of ALPSP (Audrey McCulloch) in a *Publisher Now?* interview on May 21, 2015, ALPSP has a number of areas in which they could provide assistance (McCulloch, 2015). These include assessing text and data mining (TDM) and "whether human reading effectively will be replaced by machine reading, and what effect does that have on publishing? Will research papers as we know them be consigned to nothing more than an archival record, will they change format, will researchers want to access only a paragraph of a paper with the relevant figure? How will we code and deliver that across the range of technology that will be available then? Will we regularly access these snippets of research on our smart watches (glasses/other wearable tech), or will print-outs from PDFs still be surprisingly popular". Helping to answer such questions is an important role for a collaborative group of learned societies.

The key to future success for societies is to get closer to its users, and to adapt their information-dissemination programmes to the emerging needs of their community. However, as the representative from Bioscientifica commented (meeting in August 2013), it is difficult to get society members to respond to questionnaires about their wishes, needs and intentions. Officers within the society themselves are often convinced they know what the market wants, both in the clinical side as well as the scientific side. This was reported back during meetings the author held with the Institute of Engineering and Technology (April, 2014).

Nevertheless, as societies expand their portfolio of products and services to include – besides the traditional journals, books and their e-versions – services such as conferences, meetings, blogs, association management, patents, standards, moderated lists, legal advice, etc - the scope for a more innovative approach to STEM publishing (defined broadly) may well lie through collaborative new product/service design services.

7.5. Learned society robustness

Learned societies are usually not for profit institutions. That does not mean they make financial losses. In 2004 the American Chemical Society, for example, made a surplus of almost $40 million on their journals and online databases, from total revenues of $340 million. The margin is less than Elsevier, with its profit of $1,100 million profits on revenues of $3,200 million in 2009, but it nonetheless represents a sound return for what is essentially a non-profit institution.

In a study conducted by Baldwin in 2004 for ALPSP, 154 learned society and professional association publishers worldwide were contacted by questionnaire, and 68 of these responded (Baldwin, 2004). They were almost equally divided between those who did their own publishing, and those who contracted out their publishing to a third party; some did both.

Not all responding learned societies made a surplus from their publishing activities – approximately one-third said that they did not.

Of those self-publishers which did make a surplus, the median surplus was 15% of revenue. Self-publishers reported that publishing surpluses represented a median 20% of the total society revenues; those which contracted out reported a higher median figure, 30%. Several responding societies claimed they were receiving nothing from their commercial publishing partner.

Whilst responses about how much of the surplus was applied to different areas of activity are non-comparable, they are indicative. By 'surplus' is meant the amount of journal subscription and other revenue that, after covering costs related to publishing the journal, the society or association is able to use for other activities. The percentage of the respondents which applied at least some funds to each of the areas was ranked as follows:

1. Subsidy of members' copies of the journal (96% of respondents did this).
2. Supporting the organisation in general (82%; of those who did, median 60% of surpluses was applied to this)
3. Reinvestment in the publishing business in particular (42%; median 30%)
4. Subsidy of conference fees (33%; 7%)
5. Subsidy of membership dues (32%; 15%)
6= Provision of bursaries (26%; 7.5%)
6= Public education (26%; 7.5%)
8. Reinvestment in the organisation's reserves/endowments (25%; 17.5%)
9= Provision of research grants (21%; 25%)
9= Other (21%; 25%)

According to Baldwin, if publishing surpluses were reduced (for example, by the process of being 'squeezed out' by larger publishers' Big Deals, or by a change of business model in response to market pressure), there would be a number of consequences:

- The members themselves would suffer (they would pay more for membership, more for their copies of the journal)
- Meetings and conferences which support the discipline as a whole would suffer (higher prices, fewer bursaries)
- Research would suffer (fewer grants)
- Societies themselves would suffer (less contribution to administrative costs, less contribution to reserves and endowments for future work)

- Society publishing would be affected (less reinvestment)
- The public would be affected negatively (less public education, patient support and the like)

The survey indicated that learned societies have a role to play which differs from the mainstream commercial publishers. For example, in some instances they often provide an accreditation service for their profession or discipline, monitor practices and impose discipline when needed.

Learned societies would be the natural partners in any attempt to extend the reach of STEM publishing into a subject area. They combine knowledge of the subject as well as having a mission to make it more publicly relevant and aware. Whether their mindset is focused on providing a modern communication service, using all the trappings of the Internet, is questionable given their broad overall social mission. Using their subject niche as a catalyst for a new approach to reaching out to the long tail within their society membership requires an innovative approach.

In a survey undertaken by Ware on Small and Medium sized Enterprises (SMEs) on behalf of the Publishing Research Consortium (Ware, 2009b) the author confirmed the role which learned societies could play to help those working in small entrepreneurial organisations gain access to published literature. His view was that:

> "Many professional bodies [such as learned societies] have libraries or information services that offer access to information for their members. This can be strongly valued by [society] members because it can be both cost effective and highly targeted to their specific information needs. Such libraries report difficulties in expanding their services online [to their members] because [of] budgetary or licensing constraints but if these could be overcome this could offer an attractive option for many professionals".

7.6. Libraries within learned societies

Do learned societies currently provide wide enough information support for its members through their libraries?

Linacre (Linacre, 2009) identified that there is library-related activity underway within several UK learned societies. Linacre visited 15 library services in professional institutions such as the British Medical Association, the Institution of Mechanical Engineers, Royal Institution of Chartered Surveyors, and the Law Society. Memberships ranged from 10,000 to over 100,000 per society. She interviewed their respective head of services to see what information support they provided – how they were resourced – and where they saw their services in five years' time.

The survey identified that the budget for information support amounted to around £5 per member per annum (with a range of from £3 to £10). Approximately 60% of this budget was geared towards staff costs, the rest on acquisitions, though again there was much variation in the proportions between libraries. They had on average nine staff. They performed the same supports services (cataloguing, loans, photocopying, enquiries, etc) which are found in other research libraries. Linacre also found that the typical library offered a reading room(s) which was visited by approximately 5% of total membership annually. There was an online catalogue which was open to members and non-members alike, though not usually cross searchable with other external resources. Where statistics were available, annual visits to the online catalogue were equivalent to 43% of the total membership. Constrained budgets, and difficulties getting licensed agreements with publishers were obstacles facing libraries in learned societies.

This suggests that there is a basis for learned societies to extend their information-support services providing a suitable business case could be developed, and an attractive package of services offered to members and non-members alike.

7.7. A distinctive community

Learned societies could have a crucial role to play in creating an infrastructure which supports new ways of disseminating STEM information. If affirmation is measured in terms of net contributors to social benefits then learned societies are in a privileged position.

New approaches are emerging to help learned societies reach formerly hidden nooks of society membership. No longer is the journal the only research dissemination tool. Instead, the individual article, the supporting raw data, or even particular information 'nuggets' within an article, become relevant information items. This enables innovative alternative 'packages' of information services to be considered for learned societies to supply to their members. Portals and hubs; customisation of items to meet individual membership needs (see 6.6.4) - these are new approaches which learned societies could adopt once they separate themselves from reliance on the book and journal.

Learned societies could build on the changed STEM environment to build such new paradigms based on their core strengths – a strong connection with professionals whose needs they understand and whose professional culture they seek to preserve. This sets them aside from the commercial journal publishing community whose primary role is to serve the financial interests of their owners.

7.8. Cautious approach

However, when a profession is created as a result of scarcity of skills, expertise or knowledge, professionals are often the last to recognise when that scarcity which created their community disappears. It is easier for the closed group to accept that they face competition rather than redundancy or obsolescence.

A broader vision of how the profession adapts to a new era of digital communication is lacking particularly among the smaller, specialist professions. In particular, it requires a leap in imagination for them to realise that their present publications, particularly of STEM material, is inadequate in a digital world.

Susskind asked representatives from UK professions about their views on the future robustness of learned societies, and the conclusion was that "Whether inclined towards imminent revolution or long-term evolution, there are very few professionals or providers who have thought deeply about the future and concluded that the professions will carry on indefinitely as they have for the past fifty years". According to Susskind "the strategic plans of many professional bodies and firms anticipate little more than some streamlining of twentieth century working practices" (Susskind, 2015 p45). He also comments "There is a strong sense that the professions, as currently organised, are approaching an end of an era - in the work that they do, in the identities of the providers of service, and in the nature of the service that is delivered. We are advancing into a post-professional society". This indicates short-termism which dominates operational practices among British learned societies. But it also indicates scope for new forms of information support to be provided by the new professions.

External social and technical changes in society highlight that modern strategic approaches are required to make professions relevant in a digital economy. In some respect it requires a revolution in the way learned societies operate.

Self-defence by the profession, valuable in ordinary times, becomes a disadvantage in a revolutionary period because they become concerned with threats to their professional existence and take up protectionist stances. Conservatism becomes part of the structure of a profession – in much the same way as conservatism has kept the scientific communication process unchanged in recent years. Protection of a conservative approach conflicts with adaptation to a volatile, dynamic and changing digital world (Kahneman, 1979). The competitors to many professions are digital information systems, portals and the Web, created and maintained by third parties.

There are several aspects under which professional societies will be scrutinised in future. Firstly, it has been suggested (Susskind, 2015) that they are too expensive for all within society to benefit from, maintaining the apparatus surrounding the profession adds a significant overhead cost to their services. Secondly, they rely on antiquated structures for operating their services (which are print and traditional systems based). The Internet has enfranchised the general population to undertake research for themselves - without support from professionals or their societies. Thirdly, the means whereby professionals share their expertise is conditioned by the long tail with a few professional experts serving the elite, and a large body of professionals offering a standard service to the many. Finally, the current assessment procedure of members' activities within many learned societies is inscrutable and not subject to 'openess' and 'transparency' which are features of the digital world.

These challenges are similar to the same 'perfect storm' trends and developments which confront STEM and described as STEM's dysfunctionality (chapter 6.3). In this respect the roads about to be travelled by both STEM and the professions converge, leading to disruption in both institutionalised edifices.

7.9. Future strategy for learned societies

In the new 'technology-based Internet society' Susskind predicts that machines, operated by non-specialists, will take on many functions hitherto performed by professionals in learned societies (Susskind, 2015). Based on evidence available to him he claims it "will lead eventually to a dismantling of the traditional profession".

However, professional societies could adopt alternative means for disseminating advice to its membership, based on new technology. Professional societies could put together databases of market information about people working in the field which is a first step in building any new service. They could build on the portals/hubs concepts described earlier (see section 6.6.4.1). They could explore profiles and customised delivery of all forms of research outputs, using an in-house moderator to develop the package of services.

The role of social media in keeping their society members up-to-date could become as important as delivering formal published journal literature. It may take the form of e-magazines, of news updates, of information about conferences relevant to the scope of the society. Providing easy access to web sites for members; disseminating information through ResearchGate, Twitter, even Facebook; sharing information about new standards, protocols and legal developments; there would be less of a cultural barrier in getting such data included within industry-bespoke information packages than would face commercial publishers focused on servicing research libraries with primary research literature.

Professional audiences could benefit most from the 'time switch' which the revolution in mobile phone technology has created, enabling their members to choose the time and place for information items to be delivered to them which best suit their particular career, business or personal circumstances. Use of smartphones, tablets and PCs are as ubiquitous within the professions as they are within academia/corporate R&D (see section 5.9.4.3).

An added element in this dynamic is the emergence of open access as a business model being supported by major funding agencies through mandates they impose on researchers and authors on where their research output should be made available. Open access not only offers support for members of the professional society but also for non-members, including people working in adjacent fields and undertaking cross-disciplinary work. Open access could be the principal tool for enabling learned societies to embrace UKWs within their community, and as a corollary, to become less elitist and more open and democratic in the services they offer. (see sections 6.2.5.1 and 6.4.1.1).

Once the long tail of the unaffiliated professional workers becomes part of mainstream learned society publishing then the economies of scale, which have favoured large international commercial publishers, also become available to learned societies.

It could be claimed that learned societies have not been successful in developing innovative ventures in the past and therefore would not succeed in future. However, this ignores changing market conditions, the 'perfect storm', and the 'long and increasing tail' of currently unaffiliated users. They have also been burdened by the restrictive conditions set by commercial publishers, inherited from a printed era and accepted by the institutionalised buying market (research libraries).

In future many professional services could be performed by non-professionals and machines. At present the professional societies ensure exclusivity over protection of the service package they lay claim to. They are allowed, by the 'grand bargain' with society, to regulate themselves in their own best interests. The grand bargain needs to be readjusted if learned societies are to emerge from their own 'valleys of death'. This involves breaking down the exclusivity and elitism which are protecting both STM and learned societies.

The outcome is that many smaller and sub-professions will emerge with specialist expertise, feeding on the mundane and repetitive services currently included within the professions service portfolio (and charged to users), in a process analogous to the 'twigging' within STEM and described in section 6.4.2.2. This would increase the range of new semi-learned societies who would need access to STEM. This includes many individuals who would swell the ranks of UKWs.

7.10. Summary

Subject to fundamental issues being addressed by learned societies - their cost; their reliance on tradition; their elitism; their exclusivity - there is a role for a different and more all-embracing set of activities for professions to take on in future.

> "This may be the time for developing renewed membership benefits [by learned societies], including new publications and publishing services that are offered exclusively to members. In some respects, societies may wish to look beyond institutional markets and concentrate instead on marketing directly to researchers in the field, a library bypass strategy" (Pr*esentation by Joe Esposito to Oxford University Press Delegates in New York on July 12, 2012 – see Esposito, 2012b)*

The professional society is surrounded on three sides: by libraries, funding organisations, and commercial publishers. However, another and more important factor is that structures of the established professions (lawyers, medics, accountants, librarians) are antiquated and self-serving, and ill-equipped to easily adapt to the digital age. The challenge is to find a strategy that is appropriate in modern society and which reasserts the role of professionals working together on common topics. "This marks the real end of the traditional toll-based publishing paradigm — not open access, whose benefits are largely to people outside the field, but rather the emergence of direct-to-consumer marketing, which serves to strengthen ties among societies and their membership and places the prerogatives of the researchers in a particular discipline above all others". (Esposito, 2012a).

CHAPTER 8 - DISCUSSION

8.1. OVERVIEW OF RESEARCH RESULTS

Methodology

This chapter relies on the evidence and expert opinions collected during the course of this study as described and analysed in previous chapters. It is subjective and speculative insofar as it builds upon the data available and suggests directions which the STEM industry could take in the near to mid future (five to ten years), and by derivation what this means for the Unaffiliated Knowledge Worker communities and their access to the results of scientific research.

8.1.1. Overall findings and approach

This thesis describes the context within which a healthier STEM information industry in the UK could emerge as it adapts to the digital world. However, at present there is little evidence of an 'invisible hand' (Smith, 1776) within the STEM industry driving it towards a new and potentially improved publishing paradigm. All the key drivers are external to the sector.

Particularly relevant is the extent of the overall digital transition within the UK and European economies. Using data including national digital assets, digital usage and workers, McKinsey Global Institute has developed quantified 'digital intensity' factor. This provides a comparative snapshot which shows that Europe overall operates at only an estimated 12% level, whereas the UK is at 17%. There are large and uneven variations between individual European countries, and all below the 18% level achieved in the USA, which performs comparatively stronger in sectors such as professional services. This provides the overall context within which the migration from print to digital takes place in the STEM sector ("Digital Europe: Realizing the continent's potential", McKinsey Global Institute, London, June 2016. See Buhin, 2016).

The dysfunctional nature of STEM in its print to digital migration also needs to be addressed through whether stakeholders within the industry are working together in the development of strategic initiatives which match service capabilities of the new business environment. The current impression is that caution triumphs over revolution, and Kahneman's writings that the established order fights harder to maintain its position over the innovators is particularly evident (Kahneman, 1979).

Business models need to be introduced which relate both to the way transactions are made available in digital societies at large, and also to enable the 'long tail' of knowledge workers to be included within the STEM research effort.

These business models need to address the imbalance between the (growing) supply of research outputs, and the (static or declining) institutional demand for research collections. This imbalance can be resolved by UKWs being brought within the future STEM business model but this requires innovative approaches by stakeholders.

In summary:

- The current reliance by the traditionally-orientated STEM journal publishing industry caters primarily for the information needs of a small, academic elite within the academic/corporate R&D sectors in the science research domain.
- During the past decades there has been growing antagonism between the main stakeholders largely because of different interpretations over content ownership, profit levels and acceptable business models.
- The locked-in positions of these stakeholders restricts opportunities and innovation in delivering new forms of STEM research outputs. They have created barriers to access
- Many new digital systems supporting STEM depend on technological advances being assimilated by suppliers and users. These are also challenging print-based technologies used by traditional journal publishers
- For users (researchers) there are important sociological and socio/psychology issues involved. Their needs for digital information delivery systems (products) are impacted and changing as they become 'digital natives'. More time is spent browsing, scanning, keyword spotting, non-linear reading, selective reading and less time on concentrated in-depth reading.

- There are contextual changes taking place as the adoption of efficiency-driven automation technologies impact on creativity, focus and decision-making.
- For suppliers (publishers) there is evidence that the STEM structure is no longer fit for purpose in the world of Internet and social networking - supply outstrips demand.
- One key opportunity which the combination of technology and social trends is creating is through the extension of the market for published research beyond the academic elitist sector, and to embrace unaffiliated knowledge workers (UKWs) - which increases demand.
- Reaching such wider UKW audiences requires new business paradigms and practices - allowing supply to be more cost effectively targeted to specific groups of end users
- The adoption of alternative publishing business models enables one of the current challenges facing the industry – complaints about journal pricing – to be addressed through an extension of the cost base over a larger market and the adoption of 'freemium' policies (see section 6.4.1.2)
- Including a wider community of knowledge workers within STEM leads to support for 'Big Science', dataset creation, collaboratories, citizen scientist input, globalisation of work efforts, text/data mining and modern workflow processes
- It allows the myriad of expertises in the knowledge worker communities (including UKWs) - often more practical than theoretical - to be brought within large and complex research projects
- Parallel developments in trends in professional societies (decomposition of functions) increases the range of new UKW communities (para-professionals) requiring STEM access
- Innovation within SMEs demands more appropriate STEM information systems to support their R&D needs
- Citizen scientists and other science aware communities become participants in STEM
- Society trends, driven by the Internet/Web, towards more 'openness' in ITC provides the mechanism for translating the large latent market of knowledge workers into STEM users
- This leads to greater efficiency and effectiveness in the nation's investment in scientific research
- New digital support services for science leads to different and more relevant STEM information dissemination systems underpinning research.

- Economic expansion of science (and its support services) leads to more financial resources available within society (through tax receipts) and therefore more funds available for research projects in future.
- It creates a self-perpetuating expansion and support both for the nation's research effort and also its unaffiliated knowledge worker communities.

In effect the above cycle of events is a declaration of dissatisfaction with the current atrophy in STEM. From a rejection of traditional STEM practices a healthier and more inclusive research activity would be the outcome. There are economic benefits to Science from bring UKWs into the scientific research process.

Based on the results described in the previous three chapters, a linear trend can be illustrated, leading from basic cultural issues through to an enhanced digital STEM publication system. It builds on the concepts and trends described in chapters 5 and 6 relating to the environmental agents for change which face both STEM and UKWs. These concepts are highlighted in the following flowchart.

Graph 8.1. Evolution from elitism to democratic STEM

Fundamental cultural changes are occurring	* *Tragedy of the Commons* indicates conventional STEM publishing based on demand and supply imbalance (*information overload*) is irrelevant in a digital economy * *Tipping Point* describes several factors which can stimulate an epidemic leading to cultural and market change * Functions of publishing and librarianship under microscope and could change as digital cultural influences take hold - many pundits are critical of status quo
Full cultural change takes time to take effect	* Conservatism in researchers' information seeking habits is still strong (CVs, tenure, recognition, RFE/REF evaluations) * *Economies of scale* has placed power in hands of a few large publishers * Vested interests among large commercial publishers in protecting their preferred business model is dominant * Learned societies/university presses part of a *Long Tail* in the supply chain
Economic benefits emerge from change	* *Sharing, collaboration, cooperation* – becoming more significant as singleton-based research changes to team-based *Big Science* * Embracing unique specialism inherent within knowledge workers and other

	sectors improves effectiveness of the research effort * *Twigging* enables a stream of new information frontiers to be created * *Dunbar numbers* no longer apply as social media increases personal networks
Migration from print to digital	* *Valley of death* graphically illustrates the cultural divide facing both STEM publishers in general and professions specifically in moving from print to digital * *Technology* offers a greater range of information services which are more timely and less expensive than print derivatives * Technological advances also give greater functionality in laptops, smartphones, broadband - these empower UKWs to access online services * *Digital scholars* have new way of operating and communicating (blogs; personal web pages; moderated bulletin boards)
Elitism to democracy	* An increasingly *educated society* is reducing the qualification gap between academia and citizen scientists * *Long tail* highlights that only the core STEM sector is currently addressed but a substantial long tail of opportunity among UKWs is opened up in a digital economy
Openess versus closed STEM system	* *Open access* has emerged to challenge the bedrock STEM business model - subscriptions or toll-based access * *Freemium* goes further and postulates a scenario where free sits alongside premium services in STEM * *Online services in general entertainment* and other media provide an indication of how researchers and UKWs may absorb the new digital STEM offerings
From publishing to communication	* *New business models* catering for speed, inexpensive and relevant information delivery emerge * *Gartner's Hype Life Cycle* reflects on the lack of smooth product/service adoption and that failures may be a factor of poor timing rather than irrelevance
Mindset of new generation is different	* Arrival of *Net Geners* and the *Google Generation* reflect on new generations with different IT skills * *Neuroplasticity* suggests the brain is a muscle which is stimulated and changes through activity * *The Shallows* describes the fleeting, promiscuous behaviour leading to shallow reading styles

UKWs are a significant resource currently on the periphery	* *Professions and SMEs* constitute large untapped UKW potential market * There is *cognitive surplus* among science-aware individuals which is a resource to be exploited * This has led to a growing sector of the community which can be classed as *citizen scientists* or amateur scientists with strong interest in science * The sector continues to expand as more graduates/postgraduates leave university than remain within - the *demographic trend* is cumulative * Science media for a non-specialist audience is undeveloped
Restructuring of the supply side of STEM could emerge	* *Learned societies* could take on a greater role, offering range of targeted innovative STEM services. However they face displacement by a new group of non-specialists and automation * *New players* could emerge focusing on specific disciplinary issues * *Big Science* is changing the nature of research * *Collaboratories* are demanding faster, more powerful communication models * *Designed serendipity* is yet to be fully developed within research projects
Digital technology offers new ways of doing things	* *Wisdom of the mass* gives succour to new ways of providing transparent 'refereeing' services * *Electronic publishing* developments streamline existing and future publications * *Datasets* are becoming ubiquitous, required backup for research output * *Text and data mining* is transforming the way researchers work * Supporting *workflow practices* open up broader opportunities for new information providers
Nevertheless conservatism still runs rife	* *Cult of the amateur* questions whether effective refereeing can be done outside traditional practices * *Economies of scale* reinforce the existing ways within STEM as the larger commercial publishers dominate using traditional business models * The few *User studies* which are available indicate that authors and readers still rely on the existing publishing system

The clash between conservatism and caution on the one hand and opportunity and realism on the other suggests that the change in the STEM process will be fast and furious with casualties along the way. Meanwhile, what could be seen as a virtuous STEM circle becomes an ever-increasing spiral as digital effectiveness kicks in.

8.2. ESTIMATE OF LATENT DEMAND

So far there have been few industry-wide attempts to quantify the extent of the ‘new UKW market’ for scientific content which a change in STEM would unleash. It is part of the industry’s neglect in attempting strategic and marketing forecasts of the future STEM structure. As described by Greenfield (among many others) “Sleep-walking into the unknown proudly unprepared and unreflective, and hoping for the best, is surely the most perilous [of] option[s]”. The following gives some initial signposts for providing visions of STEM’s future.

At the global level: Data in the thesis indicates there are 500 million knowledge workers worldwide (Microsoft, 2010). This is from a global population of over 7,210 million (Unesco, 2015). The number of researchers worldwide is estimated at over 7.8 million (Unesco, 2015). In developed economies knowledge workers represent 50% of the working population.

In the UK the total population in 2011 was 63.1 million and the number of knowledge workers was 11.1 million (ONS, 2011). There were 1.8 million R&D employees according to UKDBIS data for 2009.

In general is appears that of a total population, 50% have a knowledge information requirement in their working lives, but only 10% of the population can be defined as actual knowledge workers. (In the case of the UK it is 18% who are knowledge workers and 3% who are involved in R&D). These figures are indicative only - the definitions used by the data collection agencies are inconsistent.

Even though the estimates are vague and non-comparable, they are nevertheless large numbers, and the new post-digital paradigm for STEM would need to ensure that these groups are considered in any future information strategy.

The following thought piece reflects on the opportunities facing one particular aspect of the STEM package of services - individual article sales. This thought piece is based on an extrapolation from the existing situation and not on a major change or revolution in the way STEM will operate in the next five to ten years.

Table 8.1. Estimates of Demand for Articles

- In 2006/07 UK academics and students downloaded 102 million full text articles (according to COUNTER statistics)
- Assuming the rest of the affiliated UK sector (government laboratories, research institutes, pharmaceutical companies, other large corporate R&D centres, etc.) add another 40% to the above, this amounts to 143 million downloads.
- Applying a growth factor of 10% in download traffic between 2006/7 and currently, this gives almost 160 million downloads within the UK 'affiliated tent'.
- Taking the UK as being typical of the global academic and research scene, and applying the share of the research output to the worldwide download traffic estimate, the global downloads of scientific articles would be 2 billion per annum.
- The ONS has provided data which gives an estimate of 11.1 million knowledge workers in the UK (ONS, 2011).
- Of this total, 4.1 million affiliated users (academics including corporate R&D staff) in the UK generate 41 downloads each per annum (=168 million)
- In the UK, for demand in unaffiliated markets (7 million) to become as great as in affiliated markets, the average knowledge worker would need to consume 24 articles per annum. The spectrum would be anything from zero to 40 documents (the latter for those involved in fulltime R&D in UKW sectors).
- Two articles per month would rely heavily on more effective search engines, better range of services which link to articles, and a more suitable business model.

Source: These figures are based on discussions with Dr Ian Rowlands, Leicester University, in 2010/11).

Alternatively, for each article per annum that a knowledge worker in the UK downloads, the additional (download) traffic to the publisher would amount to about 7.7%. If one assumes that the average for the typical long tail user (approximately 10 article needs per annum) this would generate 110 million additional downloads.

Given the right commercial incentives this would lead to an additional market for publishers of 70% in their UK traffic, or 1.4 billion additional document downloads worldwide. This is a sizeable extension in market size available to traditional journal publishers if they would be prepared to adopt an innovative business model.

8.3. IMPLICATIONS FOR UKWs

Based on sources referred to in this thesis, the evidence is that 'perfect storm' factors could result in UKWs being brought closer within the research community during the next decade. There is an inevitability about the external technical and social trends in particular which will disturb the current STEM publishing system and reduce the barriers to access which currently exist.

Many of the trends have been around for decades. New technical initiatives; the digital consumer; open access, these have been known for some time. However, the resistances to change within the researcher-as-author community has been sufficiently powerful to prevent adoption of new and risky information procedures. The authors of research articles have sustained the existing system, assisted by past investments in physical structures (libraries; publishers) and a reward system (RAE and REF) which knows few other assessment systems than citation counts to determine how research funds should be allocated. These traditions are hard to break, and as the Finch Report (RIN, 2012) illustrates, any changes are at best peripheral, lacking in risk and in effect are purely palliatives for the existing system.

These resistances may be slow to overcome, but the trends are such that they will eventually be displaced. The increasing influence of features which are part of the Internet – transparency, interactivity, participation, free – would ensure that eventually ‘sharing’ trumps ‘protectionism’ in the future scientific landscape. As was described in the section under Environmental Change, ‘openess’ (section 6.4.1.1) and ‘freemium’ (6.4.1.2.) have emerged as features of the Internet and the elimination of the price factor in gaining access to information has become a distinct possibility in some sectors.

It is likely that in its place will emerge a more democratic and open science research space within which the opportunities for greater participation from select parts of the UKW community will be possible.

The new business paradigm may give initial preference to those non-academic research communities more closely related to the professional ethic and culture. A staggered adoption of UKWs according to the extent of their STEM needs could be envisaged.

Once access to science information is opened, the various triggers reported in 6.4.1 through 6.4.5 come into play. “The Long Tail” indicates that there is an extensive latent market to be tapped which has hitherto been hidden behind subscription-based barriers; “the Tipping Points” will suggest ambassadors who can proselytise on the benefits of an open science programme; the “Wisdom of the Crowd” will offer new ways to assess and interact with authors; the “Product Hype Life Cycle” will indicate where on the hype cycle the particular service fits and whether it moves up or down; the “Multiplier” or “Network” effects will come into play and that all the elements of the Perfect Storm will ensure that UKWs have a role in the new open science paradigm.

By the same token, socio/technological advances will move the boundaries, and provide a more effective infrastructure within which scientific communication will take place (see section 5.9 and 5.10). This includes catering for new behaviour patterns created by neurological changes; the adoption of “collaboratories” as a global research practice; and underpinning it all, ubiquitous smartphones, laptops and similar devices connecting to research results through ever more powerful networks. Demographic changes will provide an ever-growing audience of UKWs able to benefit from such changes.

Whilst the current STEM publishing system prevails, with its emphasis on toll-based access to publications, UKWs will remain peripheral to the mainstream science process. As individuals without easy access to the buying power of large research libraries, they will seek answers to their science-related issues in other ways. There is therefore a significant challenge facing STEM publishers and research librarians – either they retain traditional practices over controlled access and face the criticisms that they support exclusion, or they adapt to the culture of the Internet and embrace a more open and democratic approach to what could be seen as a public utility.

The onus is therefore on STEM information providers (which include innovative services as well as traditional publishers) to come up with processes which enable those hundreds of thousands or millions of knowledge workers to move from being outsiders from STEM to become fully engaged within the scholarly process. Existing market latency (UKWs) needs to be monetise in a way acceptable to all. Incorporation of UKWs within an enhanced research effort stands alongside, if not dominates, ‘openess’ as a strategic topic facing policy makers and funding agencies in the UK.

The implication which these changes have on the existing stakeholders will be analysed through the following sectoral SWOT analysis.

8.4. IMPACT ON STAKEHOLDERS – SWOT ANALYSIS

This chapter will explore each of the main stakeholders in the current information chain to see how robust they will be operating under changing business conditions.

Methodology

This chapter is derived from the analysis and evidence given in previous chapters. It is analytical and subjective, focusing on the strategic challenges with which each of the stakeholders are faced and the directions they may take. It speculates on how the twin issues being addressed by this thesis – the dysfunctionality of the current STEM and how UKWs may emerge as beneficiaries – will develop.

Though the input from recognised industry experts culled from desk research is referred to there is also the input from discussions with twenty external experts in their respective fields (see Methodology section 3.2) which were subject to discourse analysis. In addition, there is a personal aspect to the critical analysis and interpretations of these events based on the writer's overall forty years of industry experience in each of the stakeholder areas.

8.4.1. STEM Publishers

There are several actions publishers could take to address immediate issues. However, longer term strategic polices to arrest the claims of dysfunctionality requires substantial changes in their operations. The environmental changes are expected to exert drastic changes in the STEM paradigm, requiring a fundamental reappraisal of their future role.

In effect, much of the work of publishers and librarians in the STEM sector will be improved through adoption of automation (backroom office services). These will affect their operations. Alongside this, and in some respects competitive with it, are innovations. These rewrite the rules, coming out of the left field, and bypassing some of the operational functions held as important to STEM publishers. Adopting automation (such as digital publishing) is natural; however innovation (social networking) is threatening.

Editorial

Several pundits suggest there is a future for scientific publishers despite the impact of the 'perfect storm' (source: meetings with representatives from the Nature Publishing Group and the Institute of Physics). Additional services and products could be absorbed within their existing operations, such as offering editorial services which bring together in one place all information needs of the research life cycle (portals, see 6.6.4.1).

Publishers could learn from online services such as *Amazon* and *Google.* Welcoming users to their web sites and remembering what they last searched for; offering access to related published items which are similar to the ones last accessed; providing easy links to third party information services, even to competitor's sites, could be attractive. In effect, being more proactive in offering an enticing holistic environment for information users of all types – affiliated and unaffiliated. These may help break down some of the stuffiness which is a feature of most scientific publishers' catalogues of online services, and also reduce 'turnaways' (see section 3.3.3).

A number of opportunities for scientific publishers to adapt to the networked economy have been listed by Nielsen (Neilsen, 2009). These include:

- Include recommendations. ('More like this…' as per *Amazon*)
- Development of relevant search engines, incorporating more social features, and focused on specialist needs
- Tools for real-time collaboration by scientists in the work flow process
- Providing scientific blogging and wiki platforms
- Facilitating the creation of webs of raw data

Another set of opportunities centre around extending editorial scope into tertiary publishing – increasing reviews and assessments of research results so that they can be understood by a broader audience of UKWs (Allington, 2013). This tertiary approach was included in the earlier description of Nautilus concept

(Esposito, 2007); reaching out to support for far-flung editorial spirals is something which is tackled sparingly at present (see chapter 6.6.1).

Stimulating more interaction and online discussion/comment by the publisher and also between peers is another editorial feature which, if achieved, would reinforce the publishing brand and make it central to communication activity within groups and communities. Developing a 'prosumer' approach to generate interaction could be included (5.10.1.2).

Commercial

For publishers, the transition to Gold open access may prove difficult. They hope to maintain current levels of revenue while replacing the income stream from subscriptions and site licenses with an equivalent/greater income stream from author charges. As long as site-license revenue remains their main source of revenue, publishers would be reluctant to take risks and experiment with new potentially unsustainable and unviable business models.

This calculation will change when Gold open access reaches a critical 'tipping point' (see 6.4.1.4) and a new business philosophy will then have to be found for STEM publishing. Gold and Hybrid open access have raised the spectre of APCs (article processing charges) usurping subscription income. With APCs there is a slow growing market, some suggest that that they have already peaked (Kaufman, 2015), which limits potential for STEM publishers to find solace in replacing declining library sales with personalised purchases/payments. This issue creates a huge elephant in the room. Whether selling articles or subscriptions will be overtaken by authors paying relatively small amounts to have their articles published, or whether institutional repositories will become the new hubs for information dissemination - these will determine the scale and profitability of STEM publishing in future years.

The controversy between scientists and publishers over access to scientific information has caught the attention of investors. In a briefing note on Elsevier, Claudio Aspesi of Bernstein Research warned investors that publishers might be on the verge of falling out with scientists. He wrote "We continue to be baffled by Elsevier's perception that controlling everything (for example by limiting text and data mining applications) is essential to protect its economics" (Aspesi, 2012).

Aspesi said some of the commercial restrictions from publishers are workflow barriers facing researchers. "If the academic community were to conclude that the commercial terms imposed by Elsevier are also hindering the progress of science or their ability to efficiently perform research, the risk of a further escalation in what is already an acrimonious debate would rise substantially," he wrote. "Elsevier needs to take a much harder look at what it is doing to work well with the academic community at large". Governments and other funding bodies will need to review their funding policies if subscription-based publishers antagonise scientists too much.

If investment bankers begin to doubt the strategic directions being followed by publishers then other new entrants using innovation may be funded to fill the gap in providing an effective STEM solutions.

Marketing

There are few new institutional markets to be explored. Current focus among publishers is tapping into emerging geographic markets, such as the 'tiger economies' of South-East Asia, to compensate for static or declining sales in western countries. China in particular is being courted as a country whose commitment to research and research outputs has the potential to fill the void which the depressed library markets in the west are experiencing (Adams et al, 2009).

Another marketing strategy is to focus on knowledge worker communities. As suggested earlier (see chapter 5.4), knowledge workers operate in the professions, in SMEs, in citizen science and many other peripheral areas. There is a difference between the needs and motivations for STEM material between those based in academia and those outside. Greater understanding of the needs governing the use of research results is a prerequisite for stakeholders in STEM information in future, and this understanding will require them to take on board technical, social, psychological and administrative trends (see sections 5.9 and 6.4) which are dictating user preferences.

This may require attracting researchers into the habit of buying individual articles or information nuggets. Knowledge workers are a vast public audience with a high annual growth rate but one which can only be reached through adopting appropriate marketing approaches and incentives. It will also require price and market segmentation, allowing the tail easier and cheaper access to published material as opposed to the core researchers in academia (see 8.2).

New Business Development

Alternative opportunities for publishers include putting together information services which combine elements from formal and informal media. This requires editorial skills beyond those found in traditional journal publishing houses. Instead of an editor, the service requires a gatekeeper, searching for and including information items from various public and private sources. It needs a person or group fully in tune with the information needs of a target group. The profile is akin to a moderator of a specialist listserv. The profiles described by Gladwell in creating 'tipping points' (the Law of the Few which embrace connectors, mavens and salesmen, see section 6.4.1.4) suggest the style of leadership who could bring multimedia packages onto the global market (Gladwell, 2000).

Existing direct-to-scholar portals developed by STEM journal publishers fall short of expectations. Each portal is limited to content from just one publisher. Without cross-platform collaboration and interoperability with other sources, publisher portals remain as islands. There is a challenge in bringing together at one point all STEM publishing to enable access to common services. The past collaborative record of STEM publishing has not been encouraging. Though there are associations which act on behalf of STEM publishers – the International Association of STM Publishers being an example – these associations focus primarily on protecting members from copyright and similar legal infractions rather than building new collaborative commercial and strategic platforms. Longterm strategy operates mainly at individual corporate level rather than through industry-wide collaboration.

Using computers to match a user's profile of interests against the inflow of research outputs from different sources is another version of the above, and again relies on the adoption of new technology to reach wider audiences. The profile of interests of individual researchers – affiliated and unaffiliated - could be established by inviting individuals to fill in forms describing their research interests and/or to use web logs to reveal their past and present interests. Over time the profiles may be modified as additional search terms are used. The profiles could then be matched against latest metadata from a variety of external information resources. The many open access and publicly available sources from other third parties – possibly even competitive publishers - could be incorporated to create an extensive collection which can be used to sift through and delivered against user profiles.

Protection of confidentiality and data regulations may prove to be a limitation. Nevertheless, offering suggestions, based on search terms used, can help build up the profile, as does *Amazon* amongst others.

With the power of computing and the drive to user-centric technology it is conceivable for machines to infer a document's taxonomy on the fly and to determine whether it would suit an end user. Taxonomy on the fly systems would take advantage of machine learning to improve itself. The system would get better the more times it was used. Artificial intelligence and cognitive computing could also provide tools with which to create such relevant and innovative STEM products and services.

Strategic initiatives

The impression which STEM commercial journal publishers project is that of having 'reality distortion' - closed minds to the severity of the challenges in migrating from print to a digital paradigm. Instead they appear to build defensive walls around their current operations. They rely on protection afforded by licences and intellectual property rights - by law - at the expense of strategic initiatives - which are market driven - to enable them to survive in a transformative environment. The problem with such reliance is that "If you don't cannibalise yourself, someone else will" (Jobs in Isaacson, 2011).

In a presentation given by the chief executive of Springer, at the Academic Publishers in Europe 7th annual conference in Berlin on 24 January 2012, he gave a summary of the actions he felt publishers should take to survive. The view was from a traditional publisher with considerable success in ensuring profitable returns on business operations. He has also shown that he is prepared to adopt innovative approaches as required. For example, Springer has been a pioneer among commercial publishers in adopting open access (see Poynder, 2011a).

The take-away survival message from the above conference for publishers was:

- Publishers should focus on content and not on the many bells-and-whistles
- Publishers must learn to live with only marginally increasing library budgets
- Publishers should look to developing countries to expand their business
- Publishers should not rely exclusively on technology
- Instead, publishers should look at adopting more innovative business models

This was a conservative, cautious reaction to the business challenges facing STEM publishers in future. The question is whether publishers will be able to survive in pursuing such strategies - whether they will be able to cross the 'valley of death' (see section 5.9.4.4) in migrating from print through hybrid to digital publishing.

The issue of "Is scientific publishing about to be disrupted?" had been raised by Nielsen (Neilsen, 2009) in his blog. His argument was that there are a number of industries which have been sidelined because they were structurally unable to adapt to the new economics facing their industry. Nielsen felt that scientific publishing faced the same disruption. Large publishing houses will have to compete with new companies which are focused on meeting specific new digital demands, and this raises a different set of operational requirements. Neilsen claims that in ten to twenty years time "scientific publishers will be technology companies". "Their foundation will be technological innovation and most key decision-makers will be people with deep technological expertise" (see Neilsen, 2009).

Publishers and UKWs

Publishers have so far avoided exploiting the potential within the diffuse and personalised UKW market sectors. Risks of cannibalising their lucrative institutional sales by migrating to personal sales is a concern. They also lack the organisation, and in many cases the resources, to create an infrastructure to support selling information services to a wider community. Also, they do not have the product portfolio which the latent market of UKWs would need. In general, because of the lack of market awareness publishers are ill-equipped to create a viable strategic and commercial offering for the long tail of scholarship.

Publishers need to factor into their business plans that SMEs and many professionals have different budgetary constraints from those facing large research institutions. The price levels set by publishers for their existing products (research articles) are unlikely to be acceptable to an individual market sector. Novel, pricing models, including freemium services, need to be considered.

If publishers are to remain viable they also need to develop services which provide value at point of usage for all participants. They may have to emulate services such as ResearchGate or Academia.edu (or acquire services such as Mendeley, a policy adopted by Elsevier) or finding other means for creating a greater utility edge in the personal sector.

The emerging STEM Information Providers

Neilsen suggests there is a flourishing ecosystem of startups in scientific publishing that are experimenting with new ways of communicating research, radically different in approach from journals. According to Nielsen "Scientific publishers should be terrified that some of the world's best scientists, people at or near their research peak, are spending hundreds of hours each year creating original research content for their own blogs, content that in many cases would be difficult or impossible to publish in a conventional journal". The content will no longer be static – value-added networked services will emerge using different multimedia and enhancing it through interaction and greater sharing (Neilsen, 2009).

As commented in a listserv by the US information consultant Joe Esposito, "Always bet on the entrepreneur, as he or she doesn't care what gets broken in the process of making something new and effective" (Esposito, 2013). There is much to the current dysfunctional scientific communication process which could be broken, and high profit margins are included.

Failing such a transition from a production-based publication system to one which provides new forms of value-add, Nielsen is pessimistic about the future of scientific publishing as we know it. The structural architecture which exists in

STEM publishing runs counter to the grass roots demands of an emerging social collaborative and social networking economy.

Table 8.2. SWOT Analysis of Publishers

	STRENGTHS	WEAKNESSES
INTERNAL	*Strong support from authors *Brand recognition *High profitability potential and financial reserves *Established quality control structure (organised refereeing) *Marketing system (‘Reach’) globally	*Dependency on existing assessment system which may change *Criticisms over their control (authentication procedures) and dysfunctionality *High pricing and charges *Questionable future proposition *Fixated on protecting existing products/services (by law) * No recognisable industry leadership
	OPPORTUNITIES	***THREATS***
EXTERNAL	*Become more closely tied in with research process *More developing countries to be exploited *Extending licences to non-traditional audiences *Uncertain strength of competitive systems *Inclusion of new types of editorial services (‘Social media; tertiary publishing; portals)	*Complaints about high profit margins escalate which upset funding agencies *Blind refereeing by-pass strategies being adopted (online interactive refereeing) *New entrants targeting at broader target audiences *Legal changes – on copyright and IPR *Authors give up support for existing publishing system *Perfect storm factors leading to chaos *Impact of openness (OA) business model *Inadequate strategic vision

8.4.2. The Research Library

University libraries restrict their client base to those patrons formally affiliated with their institution. Not even alumni are automatically included in the library’s reach.

The narrowness of their current target audience needs emphasising - university libraries do not serve the public, nor knowledge workers let alone UKWs. The potential for academic libraries lies in extending their base of operations to serve knowledge workers and academia with information support services rather than with a focus on collection management.

Some pundits even claim that publishers may compete with libraries. As funding agencies and universities enforce open access mandates and publishers transition their journals from the site-license to the Gold open access model, libraries will cease to be the mechanism through which money streams from universities to publishers. In the Gold OA world, publishers' core business would be in developing direct relationships with scholars/authors (and their funders), not librarians. The scholars and their funders would control the purse strings.

Meanwhile, there has been an expansion of online resources - point of care tools, online textbooks, evidence-based databases. If cost-effective use of time, energy and talents of researchers is to occur there is a need for a professional librarian (perhaps in another guise) to help make sense of the increasingly complex world of STEM information. Researchers may not need somebody to manage the physical library - they need someone to make sure that researchers have the best information available, in the right place, at the right time, in the most cost-efficient way. In a highly competitive academic and research sector, the community can ill afford to have a traditional library or librarian approach.

As commented on Liblicence in late 2007 by Sloan, "...if this sort of trend continues will it gradually begin to marginalize the library, bit by bit? In other words, if more information becomes available freely will that lead people to think they need the library less?" (Sloan, 2007). In response, Scott Plutchak, (Director, Lister Hill Library of the Health Sciences University of Alabama at Birmingham) said of course it will. But that has been happening piecemeal for years now. People need the *library* less, but they may need the new skillsets of *librarians* more than ever (Plutchak, 2007).

According to Plutchak, "One of my gripes with the Library 2.0 crowd is that they're not radical enough. For all of the chatter about embracing change, embracing users, becoming more participative and making use of social software and social networks the focus is still firmly on the success of the library.   If we are really focused on what our communities need, we would stop talking about 'the library' altogether". Future activity does not take place in the library building – the 'new' librarians will be increasingly working with the faculty, participating in curriculum meetings, teaching in the lecture halls, holding office hours in the student lounges. That is where the new librarians belong" (Plutchak, 2007). A further role could be to ensure that the needs of the local knowledge worker communities outside their campus are also addressed.

Will librarians want to migrate towards Web 2.0 and the semantic web, in the development of ontologies and creation of quality metadata to enable targeted access to the world's STEM information resource? Will yearning for control, order and structure over vast quantities of unstructured information be the final nail in the coffin for the traditional librarian? For libraries it involves buildings and managing physical collections, tied up with physical space. For librarians it could be managing the knowledge base. This latter notion gets past their being custodians of space and physical buildings.

As reported in an Ithica research study on responses from almost 7,000 UK academics (Ithica, 2016 p 6) there has been a "notable increase … in the importance that academics assign to service-based roles of the library as compared to those that are collections-based". This has been particularly the case in the service support for undergraduates.

The peer reviewed individual article is no longer dominant in many subject areas. The article has been transformed and becomes part of a network, with links to other text services and databases. The research article is often the gateway or portal into a world of simulations, data analyses, modelling, etc. Though the article has become richer in its evolution, it has become less essential as a standalone entity. New data resources are being created, organised and supported often by the research community itself rather than the librarians. The librarian needs to cope with such changes.

Some librarians look to the Institutional Repositories (IRs) as giving them a new purpose. However, librarians have been concerned that the rate of deposition in institutional repositories has been low (without mandate), and see IRs as at best a limited success. The IRs are good places for all the digital 'grey literature'. Applying metadata to such items could be a useful additional service for librarians - generating metadata which enables local grey literature to be captured by the global search engines (and eventually vertical search engines). This grey literature could then offer further competition to the research article. Wikis, blogs and social publishing will also have some impact for the librarian, the extent of which is currently unclear. It would be short-sighted to assume that they would not have some role.

A survey entitled “Libraries: A Snapshot of Priorities and Perspectives” was conducted by OCLC in 2012 among librarians from the United Kingdom, Germany and the Netherlands which showed that library staff expect library usage to change considerably (OCLC, 2012). The increase in online visits that was expected by 71%-85% of librarians (percentages vary by country) contrasts dramatically with their expectations of low growth in physical visits. This means that users will continue to rely on libraries for getting their information, but not necessarily by coming through library doors.

So what will be the librarians’ function given the challenges to the current *modus operandum* of researchers and the changing nature of the formats for information dissemination? They will become:

- Stewards of the institution’s information needs. They will no longer be there just to buy or licence information products. Traditional library funds are being used in other ways.
- Navigators through the information morass.
- Evolve partnerships with the faculty and students. Particularly to become involved with local authors and faculty in a more proactive way.
- Developers and implementers of new services to support the diverse constituency they support.

Academic libraries may engage with publishers as competitors (Anderson R, 2013b). When site licences disappear (in favour of openess), journal-collection development becomes redundant, and digital lending of journals declines as a core service, this requires new strategic decisions from leaders in academia. With a recently released mission statement, the Harvard Library paves the way (Harvard University, 2012): “The Harvard Library advances scholarship and teaching by committing itself to the creation, application, preservation and dissemination of knowledge” as the way forward. Whilst revision to this library mission statement lacks specifics at this stage, it is clear what it omits – traditional collection development.

It also highlights actions by other university libraries – such as recently at University College London establishing a university press. A survey in the Unites States and Canada in 2008 found that 65% of research libraries were either operating a library publishing service or had plans to do so. Jisc has funded three library publishing projects in 2011 – at University of Huddersfield, UCL and University of London. There are many variations – University of Pittsburg library, for example, publishes peer-reviewed journals, but also actively cooperates with the university press to publish monographs.

The academic library of the future may depend not only on changing the balance of its functional support for its academic clients in favour of providing clarity in the complex digital information world, but also on whether it is able to effect outreach to new clients/audiences in knowledge worker communities and thereby share its cost base over more library users.

Table 8.3. SWOT Analysis of Libraries

INTERNAL		*UK customer-focused *Expertise in handling information/knowledge *Traditional centre of excellence *Resources, assets, people - robust *Free support for patrons		*Too narrow client base *Dependent on institutional funding *Serials crisis – inadequate budget *Declining footfall *Physical distance of library *Commitments to maintain library buildings
		OPPORTUNITIES		***THREATS***
EXTERNAL		*Expanding range of services beyond publication (coffee; seminars; research support) *Centre for cross disciplinary activity *Inclusion of new patrons (UKWs etc) *Establishing new partnerships *Managing the institutional knowledge base		*Cutback in library support (austerity) *The Internet and web services being first call by patrons *Private organisations supporting online delivery of education *Overhaul of higher education system (fewer universities)

8.4.3. Intermediaries

The traditional roles of intermediaries as journal subscription agents and booksellers have come under the spotlight in recent years. The number of global subscription agents has been decimated over the past two decades, and instead of a flourishing group of international agents there are now fewer than half a dozen. In October 2014 it was announced that one of the few remaining international journal subscription agents – Swets – had gone into administration. Traditional academic booksellers are also under pressure as online booksellers (Amazon) take a greater share of the book selling industry.

Aggregators and Intermediaries are therefore faced with disintermediation as publishers seek to bypass them and gain direct access to buyers of STEM. In the emerging Internet environment intermediaries are reinventing themselves based around tools such as aggregated mashups (mixing the API from different services), social bookmarks, signalling gateways, and most importantly, new search and navigation tools.

They will need flexibility to cope with a different STEM information environment. Aggregation is no longer the important role it once was (for subscription agents) as interoperability and linking come to the fore. Subscription and licensing consolidation (again performed by subscription agents) will be overtaken by national licenses on one hand and pay-per-view using micropayments styled on the iTunes or similar models on the other.

Indexing services, journal aggregators, startups, some nonprofit organisations, and library-system vendors all have expertise in producing compelling post-OA services. However, publishers only need to protect their Gold OA income to survive. All others need reasonable expectations of new revenue sources to invest in and develop new services. This potentially sets the scene for consolidation of the scholarly-communication industry, particularly because of the high risks associated with reaching out to new markets – in understanding the new user needs**.**

It has been left to 'outsiders' to run with commercial ventures seeking to exploit new commercial opportunities in digital STEM. A case in point is in document delivery where a Californian based, venture capital initiative offers a different commercial vision of the future for STEM article dissemination. If this DeepDyve business model were adapted by publishers for downloading full documents (rather than just 'renting' the article for 24 hours as per DeepDyve currently – Park, 2010), and a download price of, say, £2.50 were adopted, this would give publishers an additional income from UKW professional knowledge workers in the UK alone of £275 million. It would open up a global new market for publishers of £3.5 billion. This amounts to an addition of one-third of the current journal business (see section 8.1). It is an 'outsider' which has identified such a commercial opportunity. In the early days of DeepDyve the venture was looked at with suspicion by publishers, with many of the larger publishers choosing not to take part.

So far few organisations have succeeded in creating innovative STEM products, but with the tools available on the Internet, and the broader interest by a wider community in informatics services and social media, there is the opportunity for new digital opportunities to be developed by intermediaries in future.

Table 8.4. SWOT Analysis of Intermediaries

		STRENGTHS		***WEAKNESSES***
I N T E R N A L		*Flexible to fill information gaps *Innovative and technology focused *Support from library community *Marketing orientated		*Squeezed between sellers (publishers) and buyers (libraries) *Publishers disintermediation policies *Low margins *Lack of competitive strength
		OPPORTUNITIES		***THREATS***
E X T E R N A L		*Developing niche services in volatile digital environment *Supporting extension of Reach into UKWs *New product development *Working with partners (learned societies) *Exploiting PPV access to research outputs		*New players usurping role of traditional intermediation *Change in market demand/structure *Inadequate strategic vision *Further disintermediation by information providers (IPs)

8.4.4. Funding Agencies

Funding agencies inject financial resources from which research is performed. Traditionally their concern has been to see effective use of these resources, but increasingly they are also determining the format in which research output is delivered. In the UK the research funding agencies – including the Research Councils and Wellcome Trust - have come down on the side of supporting open access, particularly of the Gold variety. On the other hand, HEFCE, which determines the grants available to universities as part of central funding, supports a Greener approach.

A challenge which faces funding agencies is to have better information about what drives the impact of research and therefore the return on their financial investments. Impact factors of various kinds have become the main tool but these are tilted towards the formal published article and disliked in many quarters. With growth in social media, open access mandates, and greater emphasis on articles and other artefacts over the journal "package", new methods of assessing quality and impact have emerged on the scene. The traditional citation-based metrics leave out such non-traditional outputs of research in datasets, software, visualisation tools, or performance recordings, which are as — or even more — important than the journal article in some disciplines.

“The device of ‘high impact journal’ which transfers the evaluation of quality from content to journal title is the key element allowing the publishers to keep a vice on the academic world. So long as university administrators subscribe to the notion that they can evaluate their researchers in this fashion, they should not complain about high prices, because that is what the device was meant to achieve”. (Guedon, LibLicence listserv, 13 July, 2015)

The new "alternative metrics" are not without their own issues. As with any new measures, different definitions exist, the metrics are inconsistently applied, or data from comprehensive ranges of sources are limited. NISO initiated a project in 2013 to identify issues around the new altmetrics that could be solved with the adoption of standards or best practices.

There is a problem with a top down approach in dictating how individual researchers conduct and promote research. As outlined by Polanyi (in ‘Republic of Science’) there is the need to allow a decentralised approach to flourish, and not constrain science to be driven by centralised Diktats (Polanyi, 1962). The open and more all-embracing the funding structure becomes the more likely the spread of resources among a wider community, including UKWs, is achieved.

As such there is responsibility for funding agencies to ensure that they do not restrict growth in flourishing scientific areas by focusing on traditional disciplines or maintaining established metric-based agendas. Given the volatility in twigging of sub-disciplines, being able to ‘pick winners’ is an unenviable task. Balancing tradition and authority with originality is crucial for the health of scientific research.

8.4.5. Researchers and Users

It is in the hands of scholars and researchers to determine the information dissemination process which will emerge, and not publishers or librarians whose role has been to be followers rather than strategic leaders in information provision. There is inherent conservatism within these institutionalised stakeholders, which translates into preserving their core operations. This acts against a broader vision being adopted which would resolve current industry dysfunctionality and support existing and new users of STEM.

Nevertheless, the inevitability of change is strong. For example, though researchers are currently wedded to the existing referee-based system of journal publishing, the various 'perfect storm' pressures outlined in sections 5.9 and 6.4 suggest that alternative options will emerge over the next two to five years.

A growing number of 'science aware' individuals outside the academic circuit leads towards a more democratic approach to the production and use of scientific research output – as in the 'wisdom of the crowd'. The emergence of a collaborative network economy particularly around 'Big Science' puts pressure on the old elitist singleton approach. Implicit within such a networked economy is the migration from elitism to greater openess and democracy. In pursuing this migration, unaffiliated knowledge workers will be drawn into the scientific communication process, and science demographics will change.

However, there is a difficulty with building information systems on the basis of anticipated user needs. As quoted by Steven Jobs in his biography (Isaacson, 2015) he did not see the need for market research (in the design of the Macintosh computer in the early 1980's) as "customers do not know what they want until we've shown them". The Macintosh was a (successful) product designed by a small team with little outside intervention. There is therefore also a role for the benign dictator.

Table 8.5. SWOT Analysis of Researchers/Users

		STRENGTHS		***WEAKNESSES***
I N T E R N A L		*Researchers dictate direction STEM publishing takes *At the frontiers of scientific endeavor *Capable of sharing, collaboration, online interactivity *ITC-aware		*Diverse and diffuse community *Lack professional organizational skills *Acceptable refereeing system not in evidence *Research funding decided on citation metrics
		OPPORTUNITIES		***THREATS***
E X T E R N A L		*To use digital technology to create innovative Info services * Opportunity to adopt social networking *Move with the flow *Not wedded to traditional STEM procedures		*Subject to ‘information overload’ *A conservative or caution STEM development could lock out many researchers and knowledge workers *Take approach which differs from mainstream STEM *Emergence of ‘benign dictators’

8.4.6. The Disenfranchised

It is surprising how non-responsive the successful (commercially and editorially) STEM publishing industry has been in its approach to the market challenges opening up as print migrates into digital, and physical distribution goes online. The paradigm shift has exposed inadequacies – such as unanswered questions on how large the various market sectors are, how many journals exist, how many authors and research institutions are at a global level, what technological aids can be employed in providing access to research results, etc. In particular, the latent or 'long tail' has not been quantified, segmented or even considered as a commercial opportunity. Publishers have been successful for many decades in exploiting the traditional low hanging fruits at universities and research institutes.

In difficult times when the market is changing, publishers and other intermediaries ignore the dynamics which are taking place within the digital world. A growing cadre of highly educated people (graduates moving into the private sector), increasing all the time, creates new opportunities to satisfy an emergent source of demand for scientific literature albeit not necessarily in the 'research article' format. They come in different sectors with different information needs – whether as professionals, as employees within SMEs, or purely to satisfy a personal need to be kept informed.

A new approach is needed. Greater understanding of new digital information requirements by different market sectors is essential. New information services have to be designed. New business models need to be developed. Alternative long-term business strategies need to be developed. Whether the existing publishing system is best suited to do this – or whether a new breed of 'information provider' emerges from each of the research disciplines to give their members the sort of information service which suits them best – is something which only time will tell.

Table 8.6. SWOT Analysis of the Disenfranchised

		STRENGTHS		***WEAKNESSES***
I N T E R N A L		*Large numbers of disenfranchised knowledge workers *Potential significant power base *Demography acts in UKW favour (destination of graduates)		*Continue to be ignored as potential partners in STEM *Coordinated management of STEM not evident *Lack of strategic vision *Insufficient market information
		OPPORTUNITIES		***THREATS***
E X T E R N A L		*Changing market structures open up potential for UKW inclusion *Become more actively involved in research (crowd sourcing, etc)		*Conservative and elitist traditional attitudes prevail *No viable business models emerge to sustain them

Summary of Findings

Chapters 5 and 6 of this thesis go deeper into the issues raised by the Literature Review (chapter 4) through investigating basic issues facing the STEM industry in general and the various parts of the UKW community in particular. This thesis also included further analysis of the learned society as a potential key player in a new STEM information environment (chapter 7). The approach was to use the full range of information sources – printed and digital; formal and informal; face-to-face and questionnaire results - to reach an understanding of the problems and opportunities raised by including UKWs into a closer relationship with STEM information.

The conclusion is that STEM is not currently structured to support an open and more democratic information system, one which UKWs would need. STEM remains strongly dictated by its print legacy and only slowly adapting to a hybrid or fully digital information system. Its reliance on subscriptions and licences to control access runs counter to the Internet and web openness traditions. Open access business models raise prospects for enabling free information to be provided. This has evidenced itself in the remarkable rise of social media in other areas of society – media which is commercially free, technically unrestricted, socially interactive and collaborative. This would support a new set of paradigms within which researchers of tomorrow can work and be more effective.

The rise of UKWs as a powerful force riding on the back of the new openness created by the Internet and can be seen as a healthy development for science as it enables those many skills and expertises in specialised practical areas to be included within larger research projects in future. Academic research is no longer dominated by the singleton as the research focus, but rather Big Science with its multidimensional approach and need for a variety of skill sets for input has come to the fore. Sharing and collaboration of a global scale has developed which challenges researcher isolation and 'publish or perish' dictates of earlier research activities.

The inclusion of UKWs within a future STEM process also offers a platform for a healthier publication system where the traditional excess of supply ('information overload', see section 6.4.2.1) becomes balanced by an increase in the demand sector (UKWs, see 8.3). Issues such as 'serials crisis' (section 6.3.5) and much of the antagonism between stakeholders (section 6.3.3) could be removed once a healthier balance between market supply and demand forces are established. Introducing business models and paradigms which include UKWs within STEM are therefore essential strategic requirements.

CHAPTER 9.

CONCLUSIONS

9.1. Original features of this thesis

The originality in this thesis lies in its synthesis opinions, data, experiences and attitudes relating to the twin purposes of the project - to investigate the dysfunctionality of the STEM industry overall, and in particular the poor information support services provided for knowledge workers and UKWs specifically. This has been complemented by pulling together a number of data sets to present hard evidence, with the overall aim of making recommendations on how both STEM and UKWs can adapt to a new digital information environment.

The intention has been to describe and analyse the world of STEM in a new creative way. New concepts and relationships were identified outside the usual discourse within STEM which give a differeny outlook on the challenges facing the industry. These are not random connections - they link to a holistic conceptual framework, one which gives strategic concepts precedence over operational concerns. The intention throughout has been to wrap an analysis of the STEM and UKW issues - the content and arguments relating to the future of the industry - within a structure which meets the demands of academic rigour.

The world of STEM is in a bubble, constrained by attempts to resolve immediate commercial, editorial and technical issues but with an underdeveloped sense of urgency in tackling issues relating to the future. There is a sense of technological myopia among the smaller journal publishers, verging on technological arrogance among the larger ones as they continue to protect a paradigm which does not match with identifiable future trends. Universal corporate denial prevails.

Therefore, the specific novel features to this thesis' approach to the topics of UKWs within STEM are:

- It is a holistic analysis of the main STEM sectors, without giving preference to any one of the stakeholders' agendas. There is considerable baggage and legacy which has hitherto protected a print-based publishing system in STEM, and also one-sided agendas which have so far dominated commentaries about the future of the industry
- It separates the current focus on operational activities from strategic developments; the latter are likely to dominate the industry as digitisation and networking take hold. So far there has not been an open, organised or sophisticated industry platform on which to present and evaluate alternative strategic opinions
- It brings together sociological issues which affect society in general. This provides a neglected but nevertheless significant contextual backdrop within which to analyse STEM
- It offers a future in which democracy plays a greater role in science communication, as distinct from the almost elitism which has been a feature of traditional STEM activity
- It explores the imbalance in the supply and demand of the STEM system and analyses claims of the dysfunctionality in its current activities. This macro-level assessment is at the heart of the dysfunctionality claims levied against the STEM industry
- It raises the concepts of sharing, collaboration and cooperation as major drivers for future research in place of the singleton approach of 'publish or perish' which has typified STEM in the past
- it relies on a triangulation of methods in assessing developments, rather than relying exclusively on one approach, in order to get a comprehensive view of the variables involved in STEM and UKW activity
- It has developed models and concepts which are shorthand illustrations of the interaction between relevant external variables of the perfect storm
- It proposes that there are strong financial grounds for ensuring that STEM adopts a healthier business paradigm, one which enables the increased returns from including UKWs as a market sector, and by doing so would generate new funds to further expand the nation's future scientific effort

Together these give an original perspective on the future for STEM publishing in the emerging digital environment, and the role which UKWs could fill,

9.2. WHAT NEEDS TO BE DONE FOR UKWs?

As Shirky has pointed out in his book “Here comes Everybody” (Shirky, 2008), in the past supply of published information created its own demand. Now an alternative paradigm is emerging with demand creating its own supply. This means user needs are beginning to drive the creation of information products and services. Scarcity of relevant information is no longer an issue in an era of digitisation, data compilation, and tumbling costs of technology.

It is a different paradigm, demanding new business models. A linear and steady change is not an option as the forces of the ‘perfect storm’ take hold (see sections 5.9 on UKW changes, and 6.4 on STEM).

Whilst the main stakeholders argue over the merits or otherwise of promoting ‘free access’ (OA) to research outputs, the more challenging issue is to provide end users with what they need in a format which is wanted, at a price which is acceptable, at a time which is convenient, and within an overall context which enables all participating stakeholders to achieve a reasonable and sustainable financial return.

UKWs have unique information profiles, different from the academic-based researcher - their practical and business experiences can interface with pure scientific developments to provide a broader research skill set. The collaboration between big science and knowledge workers offers new perspectives and opportunities for the research process, and as a consequence drives needs for new approaches on disseminating research information.

The features of these new approaches could include:

Business Model

A business model which could be appropriate can be seen in a different industry sector. It is the use of the digital trail which end users leave in their search and discovery process as an indicator of what they might want or need from research activity. It is an approach which Amazon has adopted in alerting their customers what else they may find useful based on their buying history. The personal profile of interest is key – building up a picture of what a researcher may find useful or indispensable. Then to apply this profile against all incoming articles, commentaries, reviews, data streams, videos, software, etc, based on quality metadata which describes the content. Matches between the profile and metadata would trigger the delivery of the item to the end user. A profiled STEM delivery system, making use in future of advances in AI and cognitive computing and monitoring the digital exhaust trails left by users, would improve speed of delivery and eliminate information redundancy.

This could be achieved from a hub or portal administered by agents close to the scientific discipline. These agents are gatekeepers who would be closely aware of the overall digital needs of their particular target group.

Understanding User needs

However, more needs to be done to understand how large the latent UKW market is in the various disciplines and sectors, and what the needs are of these knowledge workers. Market segmentation and product targeting strategies may be key, but so is more professional market research and strategic planning. To offer the latent audience content to match their budget and basic requirements based on as much evidence as is available about their user needs is an essential ingredient of the new systems.

Commercial

Once such a personalised system is introduced, establishing a pricing formula which would allow end users to buy research output at a level which meets expectations of new audiences (which includes UKWs) needs to be factored in. Experiences from other information industries can again be considered.

Apple's iTunes has pioneered the use of micro-payments as the way demand and supply can be linked. Micro-payments would, if set at an 'acceptable' level, enable unaffiliated knowledge workers to become purchasers of granulated research output. The "long tail" of scientific research would be captured, enabling a greater audience to be made available for the information supply sector to compete over.

Anderson (Anderson C, 2009b) has made a strong case for basic information (the research article) to be made available for Free, with commercial returns coming from the implementation of Premium services on top of the article resources. A low unit price, counting on high elasticity in demand generated by a large expansion in the market demand from a combination of academia and knowledge workers, would be the basis for a new commercial strategy.

New focused STEM institutions

If such radical business models were introduced for STEM the institutional structures of publishers, libraries and intermediaries would give way to a service-focused set of organisations, some more 'virtual' than others, but few requiring the huge commitments to edifices, buildings or professional staff which existed in the past. Publishers will no longer have to employ armies of desk editors; library staff could be reduced in line with a reduction in collection development, curation and related services which they support, and take on new specialisms in faculty relations. Intermediaries would change their role and become more digital niche-focused in their activities.

Traditional players will need to take on new business roles or they will disappear during the next decade. Learned societies could play a leading role in developing innovative and targeted services, using portals and hubs as a key services, and based on their acceptable, non-confrontational society roles.

The requirements of the large latent audience of UKWs will determine some of the structures which will survive and emerge.

New formats

Future publications will change. The digital potential of data based publications has not yet been fully achieved. Currently, digital publications copy features of the printed publication system. However, new business models for datasets which exploit the potential of networking, collaboration, sharing and digital media could usher in a new STEM 'publishing' system. Products and services could exploit their potential to be part of a network rather than replicate the traditional practice of being part of a chain. Linking the formal publication system with the growing social media and social networking developments is still in its early days in STEM. Combining the power of the computer with human intellect (cognitive computing) offers new directions which the research process may take in some areas, which will impact on new formats and the involvement of UKWs.

Benefits

UKWs stand to benefit from such changes, but so does Science itself. UKWs have skills and expertise which can be marshalled towards enhancing the overall research effort, incorporating their contributions within a common platform in new and powerful ways. Not only will science itself be the beneficiary but so will society overall. A cycle of benefits becomes established, creating more resources which can further benefit national R&D budgets (see section 8.1).

The face of STEM publishing is unlikely to remain the same during the next decade. This is a lesson which the past decade has taught the industry - change is inevitable and can be significant. The power of the latent “long tail” is one such feature of the future of scientific communication. The Internet and concepts of the “wisdom of the crowd”, “freemium pricing”, “tipping points”, social and neurological changes, and new workflow processes are some of the many concepts which, once they merge and are adopted, will rewrite the manual for STEM communications (see sections 5.9 and 6.4).

It requires imagination and energy to run with the new potential scenarios which are opening up. Electronic STEM publishing could find a new role in the new millennium, and UKWs could be part of a wider reach for such future STEM systems. But not as a linear expansion of the current dysfunctional system.

9.3. MOVING FORWARD - ACTION PROGRAMME

A number of actions lines which the STEM industry can take in meeting the aims and objectives of this thesis emerge from the above analysis.

9.2.1. Industry Dysfunctionality

- Political issues relating to the sourcing of funds in support of research in the UK needs monitoring, particularly in view of the greater proportional sourcing from industry/business sectors in major comparator countries (Elsevier, 2013 p19).

This has an impact on the extent of research-interest among knowledge workers and their access to STEM.

- Support can also be given for national policies and initiatives in adopting 'open access' (OA). This includes Green, Gold and Hybrid, and takes into account the ultimate industry preference of Gold becoming the standard
- Nevertheless, to investigate Grey OA with quality metada as a further option (Allington, 2013). To establish how prevalent are authors' web sites, and what research content do they include. Whether funding agencies' 'executive summaries' can be enhanced and made available as part of the Green OA movement.
- Actions taken to avoid Hybrid open access opening the doors for 'double dipping' - ensuring procedures put in place to prevent dual payments (subscription and APCs) being made for the same article. Also, prevent abuse by Gold publishers who renege on publishing articles for which they have received payment (see Beall's predatory list).
- Publishers should assess the traffic currently being 'turned away' by journal publishers from their web sites to establish who are attempting access, for what reason and why they became 'turnaways'
- Measurement of quality of published scientific output (such as Journal Impact Factors) are subject to criticism, and the reliance on usage data produced by (small scale) studies gives no indication of future needs of researchers. More attention on collecting future-relevant data is required.
- Support given for initiatives such as DeepDyve and payment mechanisms such as iTunes, Paypal, etc, which provide alternative options to pay for individual items
- Alternative quality control (refereeing) systems in addition to double blind refereeing to be investigated, capitalising on social networking, transparency, speed and the wisdom of the crowd.
- Support given for copyright protection services such as Creative Commons which are less restrictive on the dissemination of research output. Licenses to publish rather than copyright protected ownership could be universally adopted.
- Innovative services in specific research areas, developed by the research community itself and subject experts, to be supported. Includes projects such as *Mendeley, Frontiers, ResearchGate*, etc.

- Experiments in alternative, multimedia STEM information products and services. Including ‘personalisation and customisation’ of information delivery through a targeted SDI approach.
- Develop subject based hubs and portals incorporating different information/media sources, and links to third party resources

More generally, to seek greater stakeholder collaboration in developing and experimenting with alternative options and strategies for coming to terms with a fully digital STEM information system. Establish a cross-industry Delphic approach to addressing the impact of the ‘perfect storm’ on the STEM industry.

9.2.2. UKW focused

- Research learned society member’s current activities in keeping up with STEM developments through more and better market research with a focus on trends. Convince learned societies that it is in their interests to professionally investigate such issues
- Undertake demographic research to quantify those sectors where regular scientific information input would be useful – including professional market identification, new product/service appraisal and market segmentation techniques
- Experiments in support of learned societies implementing new STEM-related projects should be endorsed. Capitalising on the society’s network, membership, reach and understanding of their member’s needs, the aim being to explore innovative approaches to meeting specific niche requirements.
- Focus on the key areas of unaffiliated research workers in Computers/IT, Engineering, Medicine, Bioscience, Architecture, Dentistry and Veterinary.
- Investigate business potential for a more active tertiary publication programme which give layman’s descriptions of latest relevant scientific developments (see section 6.6.1)
- Pursue the research council’s web sites as a means for making non-technical summaries of funded projects (pre and post research) available in a consistent format, understandable, accurate and as a comprehensive package.
- Assess new business models which allow end users (UKWs) to access wanted information at minimal unit cost, relying on the long tail to create a viable commercial operation

- Monitor the effects of the changes happening in the main professions and the rise of para-professions which could swell the UKW audiences further
- Extend on the template for UKW research in the UK to other countries and continents

Moving forward on the above could reduce elitism and dysfunctionality within STEM publishing. UKWs could be given equal access to the same information resources as those currently hidden behind academic garden walls. Breaching walls which currently protect the results of public funded research from accession by the private sector would be beneficial to society as a whole.

9.4. RESEARCH QUESTIONS ADDRESSED

In the initial Aims and Objectives chapter several Research Questions were posed (see section 2.4). The following are the responses which can now be given to these questions.

In essence they fall into four areas – the structure of the industry, the extent of the concerns about the industry, the impact which social trends may have and, finally, based on the above what role UKWs may play in the future.

These can be condensed into two major themes throughout the thesis. The first is that the current STEM publishing process is not fit for purpose in a digital world, and what this means for science communication in general. The second is whether the latent market of UKWs can be drawn into the scientific information system in future to make it healthier.

The Research Questions were:

Structure:

1. ***What are the overall macro-level trends which are impacting on scientific communication?***

UK society has moved from being an agrarian, through industrial to becoming a service-based economy during the past 3-4 centuries. Emerging from the service economy the importance of 'knowledge' has become apparent. Nearly 50% of the national product, and employment, are now information and knowledge-related according to authorities such as Drucker (Drucker, 1959), Machlup (Machlup, 1973), Bell (Bell, 1973), Castells (Castells, 1996) and Porat (Porat, 1977).

Knowledge workers are an increasing constituency within society as a result of the emphasis being put on raising higher education attendance rates. The effectiveness of knowledge workers could increase if they were better served by an information service which included all knowledge workers and not just the subset within academia.

2. ***What is the current structure of the information industry in the UK, specifically the research sector requiring access to scientific information?***

Sci/tech/med publishing or STEM is a small fish in a large information industry pond (Outsell, 2011). Nevertheless, it is unique in its publishing culture, having perpetuated an 'elitist' system which benefits researchers working in large research institutions (universities, research institutes and corporations), whilst the rest of the research community particularly in the private sector remains disenfranchised and unaffiliated. This has led to a 'them and us' attitude, with the beneficiaries of the legacy culture being the core academic market and the long tail of the numerically large unaffiliated researchers having been overlooked and denied access.

The research sector is separate from the rest of the information and publishing industries through its cultural legacy of being print-focused and having a unique quality control procedure.

3. ***What are the main external drivers for change?***

There is a 'perfect storm' brewing which could break down those barriers preventing wider democratic access to research results. The storm includes technological developments, social change/demography, changes in research and administrative procedures, and new business models being adopted (see sections 5.9 for UKW and 6.4 for STEM issues).

Industry Concerns:

4. ***How robust is the current scientific publishing industry in the UK. Will it adapt to address information needs of a latent knowledge worker sector?***

Scientific publishing is accused of being dysfunctional partly because it has become excessively profitable - there are accusations that large commercial journal publishers are greedy in pursuing their business operations whilst simultaneously failing to meet the needs of a new generation of users. Also, STEM publishing is structurally unsound. Reliance on a print-publishing paradigm including a tight refereeing system is anarchistic in a digital world.

The journal publishing system has too many built-in delays, and research results are only formally made available months or years after completion. In an instantaneous and free internet environment, such delays are unacceptable.

There are few indications that STEM publishers are leading the migration towards a more efficient system, one which also embraces the information needs of UKWs as well as eliminating dysfunctional aspects of current STEM publishing.

These concerns have raised questions in the media about whether the scientific publishing is fit for purpose, and funding agencies appear stuck between the need for perpetuating a system which worked well in the past, and the unknown features of what a future STEM information system should look like.

5. ***What are the opinions of leading industry observers concerning the main sci/tech/med publishing stakeholders?***

There are prominent advocates for a change in the STEM journal publishing system. In terms of tipping points, these include mavens such as Harnad, Gowers, Neilsen, Esposito and many others. These are experts who are closely involved in the industry. The consensus among these vocal pundits is that the existing toll-based system for accessing research journals is too restrictive, access being limited to those who are part of large research institutions such as universities, at the expense of the rest of society. They also point out that researchers and users are changing their information gathering activities in line with the new digital/Internet environment. They are becoming digital natives having a different mindset which alters their need for traditional STEM publishing services.

6. ***What are the main information usage patterns found among researchers?***

The current millennium sees STEM publishing industry on the cusp of change. Not only is technology bringing new digital services to the fore in society in general, this is also leading to a change in user behaviour. In the pre-Internet world, researchers read books and journal articles; the digital natives or Net Generation browse, skim and demonstrate more promiscuous search behaviour as they come to terms with information overload.

There are suggestions that behavioural change is rooted in individual's neurological adaptation to the digital world, with parts of the brain responding more rapidly to the new IT conditions, whereas the parts of the brain which supports in-depth reading of lengthy treatises is in decline (Carr, 2008 and 2010; Maguire et al, 2000; Greenfield, 2015).

Social trends:

7. ***How significant are underlying sociological trends in changing research activity?***

Underpinning changing behaviour of researchers are several sociological concepts. These include 'the wisdom of the crowds' which challenges traditional focus on blind refereeing; the 'tipping point' suggests change is created through 'viruses' being released by individuals who are leaders and trend setters in the industry; 'the long tail' highlights that there is a market beyond the restricted group of researchers within academia, a market that through its aggregation of small market niches could exceed that of the current core institutional STEM market. Other authors point to trends to 'collective intelligence' and 'designed serendipity' which stress that sharing and collaboration – particularly seen in 'Big Science' projects – is changing the way research is being undertaken. Teamwork, sharing, collaboration, transparency – they are all supported by new social networking, whereas the traditional scientific communication has been dominated by singletons and protected by legal constraints set by copyright and intellectual property.

8. ***How will researchers interact with social media in future in getting access to required scientific research results?***

Despite many advantages which the Internet world and social networking offer – speed, openness, free, interactivity, collaboration – scientific publishing has so far resisted change. Researchers as authors still rely on the established quality control system to achieve recognition for their work, tenure, promotion and new funding. Only as users do researchers engage more with social networking (University California, 2016). A number of innovative services have been developed by non-publishers to meet specific user needs for STEM information. So far these have been peripheral to the main research effort.

The pressure to change the reward system – and hence author attitudes - will come from disillusioned researchers and from funding agencies which mandate a more open information system once alternative metrics for measuring performance are put in place. These will recognise informality of social media as important forms for 'communicating' rather than 'verifying' research, and include social networking in deciding on directions which funding should take.

9. ***What other media – other than research journals – are used to keep up to date (such as datasets, crowd sourcing, etc)***

Disillusioned researchers at the coalface of research activity are frequently designers of new information systems which meet their specific needs. These are often bespoke to a given discipline, whilst recognising that there can be diversity in information needs even between sub-disciplines. By the same token there are new social media services developed outside STEM publishing which offer new ways to communicate – *LinkedIn, Skype*, webinars and moderated bulletin boards are examples.

Blog, wikis, even *Facebook, Twitter*, are also services which enable rapid communication and may find a place in supporting UKWs in future in their access to STEM.

UKWs:

10. ***Who are those not benefiting from the current system of scientific publishing? What are the main sectors within unaffiliated knowledge workers***

There are many unaffiliated sectors of society. Several are peripheral as far as their STEM information requirements are concerned; others are almost as intense as researchers in academia in their needs for access to STEM research outputs. The three categories of UKWs which have been identified as having immediate need for easy access to research output are those professions with a scientific requirement, small and medium enterprises (SMEs) and citizen scientists. However, a future more enlightened STEM system could open doors to a wider group of knowledge workers, many of which have learned societies to support them.

11. What are the main problems each of these knowledge worker sectors have in getting access to formal published research results

The barriers to access are based on subscription-based business models and licensing arrangements which restrict their ability to obtain access to research publications. Large research institutions with significant collection development budgets are the rich pickings STEM publishers primarily address. In addition, almost reluctantly, the sale of individual articles by publishers and intermediaries at high unit prices is also undertaken.

New business models, based around open access movements, could feature as determinants in creating a more equitable STEM communication system in future. Open access comes in a variety of forms but despite their existence for over a decade have at best in total only penetrated 20% of the research article market (Bjork, 2012).

12. What role will learned societies have in supporting access?

Learned societies serve members of a number of professions, but in recent decades have frequently subcontracted publication of their journals to commercial publishers. The economies of scale which commercial publishers offered, both in marketing and technical spheres, were a strong inducement for the smaller, specialised learned societies to buy into.

There is an opportunity for learned societies to take back some of the publishing functions currently controlled by commercial publishers. This would be based on adapting to technological advances as described in section 5.9.4. It requires extending beyond their comfort zones into more ITC supported areas, but as costs of participation in the latter tumble the scale of investments required become more acceptable.

Economies of scale are no longer powerful drivers for STEM in a digital/Internet world. What becomes powerful is an understanding of the specialised needs of the community which the learned society serves. By adopting personalised approaches, and developing portals and hubs which are multi-media in content, a more appropriate publishing strategy could be developed by learned societies with or without external partnerships.

The advantage of learned societies becoming central to STEM activity in future is that the financial returns which can come from publication of research results will be retained for the benefit within the science community and not distributed among shareholders in private industry.

13. How will open access facilitate greater democratisation within scientific information?

In tandem with the changing STEM publishing profile there is growing support for open access as a replacement for a subscription-based business model. In principle, open access in either its Green or Gold formats, or possibly even a more collaborative Grey network, could enable anyone to access research publications for free.

However, it is a matter of focus and priority. Open access publishers are schooled in the ways of the commercial publishing paradigm, and concentrate on providing easy and free access to the core academic market and are not proactive in stimulating demand from the various UKW sectors. There is lack of market research and marketing strategies to support their OA activities.

As a tool for easy access and democratisation of the scientific information process, open access is essential. It has raised its banner at a time when the long tail has highlighted new market opportunities. These market opportunities require sharing, collaboration, interactivity and free conditions which come with open access.

14. What is the impact on stakeholders in providing UKW researchers' information needs?

All stakeholders will be affected by the 'perfect storm' of external changes, particularly larger commercial journal publishers. Publishers need to traverse the "valley of death" (section 5.9.4.4) and adopt more digital-friendly services. Large commercial publishers still have ownership issues to contend with. Librarians may see a greater role for themselves in running institutional repositories, at the expense of their current activities in physical collection development (see section 8.4.2). Funders may change the way STEM is disseminated but only after suitable metrics are in place to ensure funded projects deliver quality research (see section 8.4.4). It is the research community itself, together with STEM aware knowledge workers, which could effect the greatest changes in the STEM information system during the next decade, supported by on-going technological developments.

15. What needs to be done to enfranchise UKWs in the UK in future?

As indicated in section 9.1 above, a different business paradigm is required. It would incorporate Green/Gold open access. It could include learned societies as levers into the professionals. It would embrace a series of different media types, not just journals. Portals and hubs which bring together formal and informal information types, and targets them using profiling and customisation for a targeted audience, would offer a counterbalance to the 'eat all you can get' from services such as Google.

The need is for information agencies to proactively work with representatives from subject areas to ensure the full range of support services is available to meet developing market needs. Moderators could replace editors as leaders in the information chain as organisers and administrators of new information packages suitable for academic and UKW audiences alike.

It needs more strategic thinking and less operational navel gazing and protectionism of an industry structure which served the community well in the past but is now facing a different set of environmental conditions. A new approach to strategic scenario building should be made to help provide guidelines along which the new STEM information system within a digitally empowered UK society can develop.

10. APPENDICES

10.1 BIBLIOGRAPHY

Ackoff, R. 1989. "From Data to Wisdom". *Journal of Applied Systems Analysis* 16: 3–9

Adams, J. C. King and N. Ma. 2009. "Global Research Report – China". In *Research and Collaboration in the New Geography of Science.* Philadelphia: Thomson Reuters.

Allington, D. 2013. "On Open Access, and why it's not the answer". Allington blog. 15 October 2013. Accessed May 5, 2016. http://www.danielallington.net/2013/10/open-access-why-not-answer/#sthash.aQfG6d1A.dpbs

Anderson, C. 2004. "The Long Tail." *Wired* 12(10). Accessed May 5, 2016. http://archive.wired.com/wired/archive/12.10/tail.html

Anderson, C. 2008a. "Free! Why $0.00 is the Future of Business." *Wired* 16 (3). Accessed September 25, 2015. http://archive.wired.com/techbiz/it/magazine/16-03/ff_free?currentPage=all

Anderson, C. 2008b. "The End of Theory: The Data Deluge Makes the Scientific Method Obsolete". *Wired* 16 (7). Accessed September 25 2015. http://archive.wired.com/science/discoveries/magazine/16-07/pb_theory/

Anderson, C. 2009a. *The Longer Long Tail – How Endless Choice Is Creating Unlimited Demand*. 2009. London: Random House Business Books

Anderson, C. 2009b. *Free – The Future of a Radical Price*. 2009. London: Random House Business Books

Anderson, C. and M. Wolff. 2010. "The Web is Dead. Long Live the Internet". *Wired.* September 2010. Conde Nash.

Anderson I. 2008. "The Audacity of SCOAP^3." in *ARL: A Bimonthly Report on Research Library Issues and Actions*. April, 12-13, 2008. Washington, DC: ARL, CNI, and SPARC, 257. pp12-13. Accessed May 5, 2016. www.arl.org/storage/documents/publications/arl-br-257.pdf

Anderson, K. 2011. "Uninformed, Unhinged, and Unfair — The Monbiot Rant." *Scholarly Kitchen,* 1 September 2011. Accessed May 5, 2016. http://scholarlykitchen.sspnet.org/2011/09/01/uninformed-unhinged-and-unfair-the-monbiot-rant/

Anderson, R. 2011. "OA Rhetoric, Economics, and the Definition of 'Research' ". *Scholarly Kitchen,* 7 September 2011. Accessed May 5, 2016. http://scholarlykitchen.sspnet.org/2011/09/07/oa-rhetoric-economics-and-the-definition-of-research/

Anderson, R. 2013a. "Signal Distortion – Why the Scholarly Communication Economy Is So Weird". *Scholarly Kitchen,* 14 May 2013. Accessed 25 September 2015. http://scholarlykitchen.sspnet.org/2013/05/14/signal-distortion-why-the-scholarly-communication-economy-is-so-weird/

Anderson, R. 2013b. "On the Likelihood of Academia 'Taking Back' Scholarly Publishing". *Scholarly Kitchen,* 27 June, 2013. Accessed May 5, 2016. http://scholarlykitchen.sspnet.org/2013/06/27/on-the-likelihood-of-academia-taking-back-scholarly-publishing/

Appleyard, A. 2010. "British Library Document Supply – a Fork in the Road." *Interlending and Document Supply.* Leeds: Emerald: 38 (1): 12-16.

Alok Jha.. 2012. *The Guardian*. 23 May, 2012. Accessed September 25, 2015. http://www.theguardian.com/science/2012/may/23/text-mining-research-tool-forbidden.

Arbitron and Edicon Research. 2013. "The Infinite Dial 2013: Navigating digital platforms". Accessed May 5, 2016. See http://www.edisonresearch.com/wp-content/uploads/2013/04/Edison_Research_Arbitron_Infinite_Dial_2013. Pdf

Aspesi, C. 2012. "Reed Elsevier: A Short History of Two Days in July (and Why Investors Should Care)". (See Poynder, 2012).

ARL. 2008. "Current Models of Digital Scientific Communication – Results of an Investigation Conducted by Ithica for the Association of Research Libraries". Washington, DC, USA: Association of Research Libraries.

ARL. 2009. "ARL Annual Statistics 2008-09". Washington, DC, USA: Association of Research Libraries.

ARL. 2011. "ARL Annual Statistics 2010-11". Washington, DC, USA: Association of Research Libraries.

Baldwin, C. 2004. "What Do Societies Do with Their Publishing Surpluses?". Shoreham-by-Sea, West Sussex, UK: Association of Learned and Professional Society Publishers. Accessed 25 September, 2015. http://www.alpsp.org/Ebusiness/ProductCatalog/nfpSurpluses.aspx?ID=48

Ball, C. 2013. “Most people in the UK do not go to university – and maybe never will”. *The Guardian Higher Education Network* . Blog. 4 June, 2013.

Bartling, S. and S. Friesike. 2014. *Opening Science - The Evolving Guide on How the Web is Changing Research, Collaboration and Scholarly Publishing*. Dynamic book edited by Sonke Bartling and Sascha Frieske. Accessed 16 October 2014. http://book.openingscience.org/

Battelle, J. L. 2005. *The Search: How Google and Its Rivals Rewrote the Rules of Business and Transformed Our Culture*. New York, USA: Portfolio

Beise, M. and H. Stahl. 1999 ”Public research and industrial innovations in German”. *Research Policy.* Amsterdam, NL: Elsevier, vol. 28(4), pages 397-422, April, 1999.

Bell, A. 2012. “Wider open spaces: freely accessed papers are simply points in a constellation of scientific communication with the public, says Alice Bell.” *Times Higher Education.* 19 April, 2012. Accessed May 5, September 2016. http://www.timeshighereducation.co.uk/419684.article

Bell, D. 1973. *The Coming of Post-Industrial Society: A Venture in Social Forecasting*. New York: Basic Books.

Bergstrom, C.T. and T.C. Bergstrom. 2004. “The costs and benefits of library site licenses to academic journals”. *PNAS*. January 20, 2004. vol. 101 no. 3. Seattle, WA: University of Washington. Accessed May 5, 2016. www.pnas.org/content/101/3/897.full.pdf+html

Bernard of Chartres, 12th century. See Newton, 1668.

Bjork, B-C. and A, Roos, and M, Laura. 2008. “Global Annual Volume of Peer Reviewed Scholarly Articles and the Share Available via Open Access Options.” *Proceedings ELPUB2008 Conference on Electronic Publishing.* Toronto, Canada: June 2008: 1-10. http://elpub.scix.net

Björk, B-C. and A. Roos and M. Lauri. 2009. “Scientific journal publishing: yearly volume and open access availability.” *Information Research,* **14** (1) paper 391. Accessed May 5, 2016. http://InformationR.net/ir/14-1/paper391.html

Björk, B-C. 2012a. “Open Access versus Subscription Journals – A Comparison of Scientific Impact”. *BMC Medicine*, 10: 73. Accessed May 5, 2016. http://www.biomedcentral.com/1741-7015/10/73

Björk, B-C. 2012b. "The Hybrid Model for Open Access Publication of Scientific Articles – A Failed Experiment?" *Journal of the American Society of Information Sciences,* 63 (8): 1496-1504

Bohannon J. 2016. "Hate journal impact factors? New study gives you one more reason". *Science.* July 6, 2016. Sciencemag.org

Bollen, J. and H. van de Sompel and R. Luce. 2005. "Toward alternative metrics of journal impact: a comparison of download and citation data". *Information Processing and Management.* 41:1419–1440, 2005,

Brand, S. 1984. "Information Wants to Be Free. Information Wants to Be Expensive". *Whole EarthReview.* May 1985: 49.

Brienza, C. 2011. "Communication or Credentialing? On the Value of Academic Publishing." *Impact of Social Sciences*, 5 May 2011. Accessed May 5, 2016. http://blogs.lse.ac.uk/impactofsocialsciences/2011/05/05/communication-or-credentialing/

Brooks, D. 2012. *The Social Animal: A Story of How Success Happens.* 2nd ed. London: Short Books.

Brown, A. 2009. "Digital Britain Needs Access to Science Journals, not YouTube." *The Guardian*, 5th February 2009. Accessed 5May 5, 2016. https://www.theguardian.com/technology/2009/feb/05/science-journal-access

Brown, D. 2003. "Is This the End of the Article Economy? A Strategic Review of Document Delivery." *Interlending and Document Supply*, 31 (4): 253-263.

Brown, D. 2004. "Interlibrary Lending and Document Delivery – An Overview". *Vine.* Vol 23, Issue 2, pp 3-6. Emerald Publishing Group, Bradford, UK

Brown, D. and R. Boulderstone. 2008. *The Impact of Electronic Publishing: The Future for Libraries and Publishers.* K.G, Saur, Munchen: Germany. 2008.

Brown, D. 2010. "Repositories and Journals: Are they in conflict? – A literature Review of relevant literature". *Aslib Proceedings* Vol 62 issue 2, pp 112-143. Emerald Publishing Group, Bradford, UK:

Brown, D. 2016. *Access to Scientific Research: Challenges facing Communication in STM*. IFLA Global Studies in Libraries and Information. K.G. Saur. Munchen: Germany 2016.

Brown, T. 2014. "Hightable with Tracey Brown: Asking for Evidence to make Sense about Science". *Oxbridge Biotech Roundtable*, 5 July 2014. Oxford. Accessed May 5, 2016. http://www.senseaboutscience.org/blog.php/100/hightable-with-tracey-brown-asking-for-evidence-to-make-sense-about-science

Brynjolfsson, E. and Y. J. Hu and D. Simester. 2011. "Goodbye Pareto Principle, Hello Long Tail: The Effect of Search Costs on the Concentration of Product Sales*". Social Science Research Network*. Accessed May 5, 2016. http://ssrn.com/abstract=953587

Budd, J. M. 2006. "Discourse analysis and the study of communications in LIS". *Library Trends.* 55(1), 65-82.

Bughin J, et al. 2016. "Digital Europe: Realizing the continent's potential". London, UK: McKinsey Global Institute. June 2016.

Capgemini UK. 2008. "The Information Opportunity*".* Harij Ramesh, Capgemini. London. (See Ramesh, 2008).

Carr, N. 2008 "Is Google Making Us Stupid? What the Internet is doing to our brains*." Atlantic Magazine,* July/August 2008 . Accessed May 5, 2016. http://www.theatlantic.com/doc/200807/google

Carr, N. 2010. *The Shallows – How the Internet is Changing the Way We Think, Read and Remember.* London and New York: W.W. Norton and Co.

Carr, N. 2016. *The Glass Cage: Who Needs Humans Anyway?* USA: Vintage Books/Random House.

Castells, M. 1996. *The Information Age; Economy, Society and Culture. Volume 1, The Rise of the Networked Society.* Oxford: Blackwell Publishers

CBD. 2009. *CBD Directory of British Associations and Associations in Ireland. 2009. 19th edition*. Beckenham, Kent: CBD Research Ltd..

CEPA. 2008. "Activities, costs and funding flows in the scholarly communications system in the U.K". Cambridge Economic Policy Associates. London, UK: Research Information Network. Accessed May 5, 2016. http://www.rin.ac.uk/our-work/communicating-and-disseminating-research/activities-costs-and-funding-flows-scholarly-commu

CEPA. and M. Ware. 2011. "Heading for the Open Road: Costs and Benefits of Transitions in Scholarly Communication*"*. London: RIN. Accessed May 5, 2016.

http://www.rin.ac.uk/our-work/communicating-and-disseminating-research/heading-open-road-costs-and-benefits-transitions-s

Chawla, D S. 2015. "Nature Publishing to merge with the world's second biggest science publisher". *Science.* January 15, 2015.

CIBER. 2009. "The Economic Downturn and Libraries - A Global Survey of the World's Libraries in Challenging Times". Charleston, SC, USA: Charleston Observatory, 2009. Accessed May 5, 2016. http://ciber-research.eu/download/20091103-charleston-survey.pdf

CIBER. 2010. "Research support services: What services do researchers need and use?" CIBER, November 2010. London, UK: Commissioned by RIN and OCLC.

CIBER. 2011. "Are Social Media Impacting on Research?" Charleston SC, USA: Charleston Observatory, USA, 2011

Cooney, C.M. 2012. "Downscaling climate models: sharpening the focus on local-level changes". *Environmental Health Perspectives*, 120 (1). January, 2012.

Cox, J. and L. Cox. 2008. "Scientific Publishing Practice – Academic Journal Publishers' Policies and Practices in Online Scientific Publishing". Third Survey. Shoreham-by-Sea, West Sussex, UK: Association of Learned and Professional Society Publishers (ALPSP). 2008.

Crow, R. 2002. "The Case for Institutional Repositories". Scientific Publishing & Academic Resources Coalition (SPARC). Washington, DC: Association of Research Libraries.

Crystal, A, and J. Greenberg. 2006. "Relevance criteria identified by health information users during web searches." *Journal of the American Society for Information Science and Technology*, 57 (10): 1368-1382.

CSHE. 2011. "Final Report - Assessing the Future Landscape of Scholarly Communication: An Exploration of Faculty Values and Needs in Seven Disciplines". University of California Berkeley, Center for Studies in Higher Education: Accessed September 25, 2015. http://www.cshe.berkeley.edu/publications/final-report-assessing-future-landscape-scholarly-communication-exploration-faculty

Davis, P. 2014. *The Scholarly Kitchen*. Society of Scholarly Publishing. July 2014.

Dawson, A.H. and J. Scanlan. 2016. "The economic essentials of digital strategy – a supply-and-demand guide to digital disruption", *McKinsey Quarterly*. London: March 2016.

Day. E. 2013. "Aaran Schwartz: hacker, genius...martyr?" *The Guardian*, 2 June, 2013.

Dean, D. and C. Webb. 2011. "Recovering from information overload." *McKinsey Quarterly.* January 2011. Accessed September 25, 2015. http://www.mckinsey.com/insights/organization/recovering_from_information_overload

Denscombe M. 2014. "The good research guide for small-scale social research projects". (4th edition). Maidenhead: Open University Press. (Chapter 12 (interviews); Chapter 14, (documents)).

Dewatripont, M.,V. Ginsburgh, P. Legros, and A. Walckiers. 2006. "Study on the European Commission (Research Directorate-General). Accessed May 25, 2015. http://ec.europa.eu/research/science-society/pdf/scientific-publication-study_en.pdf

Dilek-Kayaoglu, H. 2008. "Use of electronic journals by faculty at Istanbul University, Turkey: The results of a survey". *The Journal of Academic Librarianship*. Volume 34. Issue 3 May, 2009 p 239-247.

Dobbins, M. and S.M. Jack and H Thomas and A Kothari. 2007. "Public Health Decision Makers' Informational Needs and Preferences for Receiving Research Evidence." *Worldviews on Evidence-Based Nursing* 4 (3): 156-163

Doctorow, C. 2015. *Information Doesn't Want to be Free - Laws for the Internet*. San Francisco: McSweeney's. 2015.

Drucker, P F. 1959. *Landmarks of Tomorrow.* New York: Harper and Row. 1959

Drucker. P F. 1973. *Management: Tasks, Responsibilities, Practices*. New York: Harper and Row. 1973.

Duggan, M. and J. Brenner. 2013a. "The Demographics of Social Media Users". Washington, DC: Pew Research Center's Internet & American Life Project. February 14, 2013. www.pewresearch.org

Duggan, M. and A. Smith. 2013b. "Social Media Update". Washington, DC: Pew Research Center's Internet & American Life Project. December, 2013. www.pewresearch.org

Dunbar, R.I.M. 1992. "Neocortex Size as a Constraint on Group Size in Primates." *Journal of Human Evolution* 22 (6): 469–493. 1992.

Eagleman, D. 2011. *Incognito: the Secret Lives of the Brain.* Edinburgh: Canongate Books.

Economist. 2013. "Scientific publishing has changed the world, now it needs to change itself." *Economist.* October 19, 2013.

Economist. 2015. "The Truly Personal Computer". *Economist*. 28 February, 2015.

Elsevier Press Release dated 9 June, 2011.

Elsevier. 2013. "International Comparative Performance of the UK Research Base – 2013" Elsevier Science Report for the UK's Department of Business, Innovation and Skills (BIS). October, 2013.

Ernst and Young. 2012. "University of the Future – A Thousand Year Old Industry on the Cusp of Profound Change". Ernst and Young (Australia). 2012.

Esposito, J. 2007. "Open Access 2.0: The Nautilus: Where - and How - OA Will Actually Work." *The Scientist,* 21 (11): 52.

Esposito, J. 2010. "A Library Card under the Christmas Tree". Blog contribution dated January 2010 on *The Scholarly Kitchen*, Society of Scholarly Publishing. http://scholarlykitchen.sspnet.org/2009/12/01/a-library-card-under-the-christmas-tree/

Esposito, J. 2012a. "Putting Society Publishing in Context." *The Scholarly Kitchen*, July 16, 2012.

Esposito, J. 2012b. Presentation to Oxford University Press Delegates. New York. July 12, 2012.

Esposito, J. 2013. "Open Access 2.0: Access to Scholarly Publications Moves to a New Phase." *Scholarly Kitchen*, February 2013.

European Commission. 2003. "What is an SME?". European Commission, Internal Market, Industry, Entrepreneurship and SMEs. EU Recommendation 2003/361. .

Eurostat. 2007. "Highly Qualified Workers in Science and Technology. Statistics in Focus". Eurostat. 103/2007.

Evans, P. and T. Wurster. 2000. *Blown* to *Bits*: *How the New Economics of Information Transforms Strategy.* Cambridge, MA, USA: Harvard Business School Press

Eveleth, R. 2014. "'Academics write papers arguing over how many people read (and cite) their papers". *Smithsonian.com.* March 2014.

Faulder and Cha. 2015. *Access to Research Initiative - background to the pilot and some early findings*. London: Publishers Licensing Society. 2015.

Faxon Institute. 1991/2. “Examination of Work-related Information Acquisition and Usage among Scientific, Technical and Medical Fields”. Boston, USA: The Faxon Institute. Grey Literature.

Fenner, M. 2010. “Researchers’ reasons for publishing their works”. *PLOS Blog*. Nov 28, 2010. Accessed September 2015. http://blogs.plos.org/mfenner/2010/11/28/researchers-reasons-for-publishing-their-work/

Finch Report. 2012. See RIN. 2012.

Fink, A. 2014. *Conducting Research Literature Reviews (4th edn)*. Thousand Oaks, CA: Sage

Ford, M. 2016. “This isn’t crying wolf: Machines will take white-collar jobs during the next administration”. Open latter to next US President. April 4, 2016.

Forrester Research. 2001. “Portals Squeeze Business Media”. Cambridge, MA, USA: Daniel P O’Brien, Forrester Research. December 2001.

Gale J. 2010. “Discursive Analysis: A research approach for studying the moment-to-moment construction of meaning is systemic practice”. *Human Systems: The Journal of Therapy, Consultation & Training*. Volume 21, Issue 2, 2010. Pp7-37.

Gardner, T. and S. Inger. 2012. “How Readers Navigate to Scholarly Content. Comparing the changing user behaviour between 2005 and 2012 and its impact on publisher web site design and function.” Renew Training, Abingdon, UK: ISBN 978-0-9573920-3-8

Gartner. 2014. *Hype Cycle Methodologies*. Stamford, CT, USA: Gartner, Inc. Accessed September 25, 2015. http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

Gilder, G. 1993. *Wealth and Poverty.* p xi. San Francisco, CA, USA: ICS Press

Giles, J. 2007. “PR’s ‘pit bull’ takes on open access. Journal publishers lock horns with free-information movement”. *News @ nature.com*. 25 January, 2007.

Ginsparg, P. 2006. “As we may read”. *Journal of Neuroscience,* 26 (38): 9606-9608.

Gladwell, M. 2000. *The Tipping Point – How Little Things Can Make a Big Difference*. Boston, USA: Little Brown and Co.

Gladwell, M. 2008. *Outliers: the story of success*. November 2008. Boston, MA. USA: Little Brown & Co.

Gorman, G. E. and P. Clayton. 2005. *Qualitative research for the information professional: a practical handbook.* (2nd edition), London: Facet. Chapter 8 (interviewing).

Gowers, T. W. 2009. "Is Massively Collaborative Mathematics Possible?" Gowers' weblog, January 27, 2009. Accessed May 5, 2016. http://gowers.wordpress.com/2009/01/27/is-massively-collaborative-mathematics-possible/

Gowers, T. W. 2012. *The Sunday Times*, 19 February 2012.

Gowers, T.W. 2014. "Elsevier journals - some facts". Gowers's Weblog. Accessed May 5, 2016. https://gowers.wordpress.com/2014/04/24/elsevier-journals-some-facts/

Greenfield, S. A. 2005. "Biotechnology, the Brain, and the Future." *Trends in Biotechnology* 23 (1): 34-41. 2005

Greenfield, S.A. 2014. *Mind Change: How digital technologies are leaving their mark on our brains*. London. Penguin Random House. 2014.

Guedon, J-C. 2004. "The 'Green' and 'Gold' Roads to Open Access: The Case for Mixing and Matching." *Serials Review,* 30 (4): 315

Guedon, J-C. 2015. Liblicence. 13 July, 2015.

Haank, D. 2011. See Poynder. 2011a.

Hahn, K. 2008. "Research Library publishing services: new options for university publishing". Washington, DC: Association of Research Libraries.

Hall, M B. 2002. *Henry Oldenburg: Shaping the Royal Society*. Oxford: Oxford University Press

Hannay, T. 2014 "Science's big data problem". *Wired.* August, 2014.

Hardin, G. 1968. "The Tragedy of the Commons." *Science*, Vol. 162, No. 3859. December 13, 1968, pp. 1243-1249

Harnad, S. 1994. "Scientific Journals at the Crossroads: A Subversive Proposal for Electronic Publishing." In *Publicly Retrievable FTP Archives for Esoteric Science and Scholarship: A Subversive Proposal,* edited by Ann Okerson & James O'Donnell. Washington, DC: Association of Research Libraries.

Harvard University. 2012. “Major Periodical Subscriptions Cannot Be Sustained”. Cambridge, MA, USA: Harvard University, Faculty Advisory Council Memorandum on Journal Pricing. 17 April, 2012. Accessed September 25, 2015. http://isites.harvard.edu/icb/icb.do?keyword=k77982&tabgroupid=icb.tabgroup143448

Henry, S. and A. Gilmore and D. Gallagher. 2007. "E- marketing and SMEs: operational lessons for the future". *European Business Review,* Vol. 19 Iss: 3, pp.234 - 247

HEFCE. 2014. “Policy for open access in the post-2014 Research Excellence Framework”. Higher Education Funding Council England. Updated July 2015. Accessed September 25, 2015. http://www.hefce.ac.uk/pubs/year/2014/201407/

HESA. 2010. “Destinations of Leavers from Higher Education Institutions 2008/09 and 2019/10”. June 2010. Cheltenham, UK: Higher Education Statistics Agency.

HESA. 2014. “Higher Education – Statistics for the United Kingdom”. June 2014. Cheltenham, UK: Higher Education Statistics Agency.

Hey, T. and A.Trefethen. 2003. “The Data Deluge: An e-Science Perspective”. UK e-Science Core Programme. Accessed September 25, 2015. http://eprints.soton.ac.uk/257648/1/The_Data_Deluge.pdf

Horrigan, J B. 2006. “The Internet as a resource for news and information about science”. Washington, DC: Pew Internet and Life Project, Washington DC. Accessed August 2012. http://www.pewInternet.org

House of Commons Science and Technology Committee. 2004. “Scientific Publications: Free for All? Tenth Report of Session, 2003-04”. London: House of Commons Committee Scientific Publications.

IDC. 2009. “Hidden Costs of Information Work: A Progress Report”. IDC #217936. Framingham, MA, USA: International Data Corporation

ICSTI. 2011. Annual 2011 Conference. International Council of Scientific and Technical Information. Beijing, China: ICSTI, Paris, France.

Internet Statistics. 2014. “Internet World Statistics”. Accessed September 25, 2015. http://www.internetworldstatistics.com.

Isaacson, W. 2011. *“Steve Jobs*”. New York, USA: Simon and Shuster, November 2011.

Ithica S&R, Jisc, RLUK. 2016. UK Survey of Academics 2015. USA: Ithica, NY. June 2016

ITU. 2015. "*Facts and Figures, 2015*". International Telecommunications Union. Accessed September 25, 2015. http://www.itu.int/ITU/statistics/Pages/deafault.aspx.

Jeffrey K G. 2012. GOAL listserv, 21 June 2012

Jisc. 2012. *"Value and benefits of text mining*". 2012. Diane MacDonald and Ursula Kelly for Joint Information Services Committee, Bristol: Viewforth Consulting.

Jisc and BL. 2012. "Researchers of Tomorrow – the research behaviour of Generation Y doctoral students". 28 June, 2012. Bristol and London: Joint Information Services Committee**.** Accessed September, 25, 2015. https://www.jisc.ac.uk/reports/researchers-of-tomorrow

Kahneman, D. and A.Tversky 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica* 47 (2): 263.

Kanter, R M. 2003. "Leadership and the Psychology of Turnarounds". *Harvard Business Review*, June 2003.

Kaufman, R. 2015. "Growing Your Open Access Business". *Publishers Weekly*, Frankfurt Show Daily. 14 October, 2015.

Keen, A. 2007. *The Cult of the Amateur: How Today's Internet is Killing our Culture*. London: Doubleday Publishing/Penguin/Random House. 2007.

Kelly. K. 2013. "Better thanHuman: Why Robots will - and must - take our jobs". *Wired.* Vol 21. No 5. May 2013.

King, D.W. and C.Tenopir and S.Choemprayong and L.Wu. 2009. "Scholarly journal information seeking and reading patterns of faculty at five U.S, universities. *Learned Publishing* [Internet], 2009:22 (2).

King, D.W. and C.Tenopir. 2011. "Some economic aspects of the scholarly journal system". In *Annual Review of Information Science and Technology.* Vol 45. Medford, NJ. Blaise Cronin, ed. Information Today Inc. 2011. Pp 295-366.

Knovel. 2013. "Engineers Searched Online for Equations More Frequently in 2013, But Were Dissatisfied with Results." New York: Knovel. Accessed September 25, 2015.. http://why.knovel.com/news-a-events/2979-engineers-searched-online-for-equations-more-frequently-in-2013-but-were-dissatisfied-with-results-html

Kopelman J. 2007. “The Penny Gap”. First Round Capital. Accessed 25 September 2015. http://redeye.firstround.com/2007/03/the_first_penny.html

Kornhauser, W. 1962. “*Scientists in Industry: Conflict and Accommodation*”. 1962

Krippendorf K. 2013. “*Content analysis: an introduction to its methodology”*. London: Sage Publishing. 2013.

Krugman, P. 2013. “The Facebooking of Economics”. *New York Times*. December 17, 2013

Lanier, J. 2011. You are not a Gadjet: A Manifesto. February 2011. USA: Penguin.

Lieberman, M.D. 2013. *Social: Why Our Brains Are Wired to Connect*. New York, NY: Crown Publishing

Linacre, C. 2009. “Survey of Library Services in UK Professional Bodies.” 2013. Grey literature.

Mabe, M.A. and M. Amin. 2001. “Growth Dynamics of Scholarly Journals.” *Scientometrics* 51(1), 147-162.

Mabe, M.A. 2003. “The Growth and Number of Journals.” *Serials* 16 (2):191-197

Mabe, M.A. 2009. “Scholarly Publishing”. *European Review* 17 (1): 3-22)

Machlup, F. 1973. *The Production and Distribution of Knowledge in the United States.* , 1973. Princeton, NJ, USA: Princeton University Press

Maguire, E.A. and D.G. Gadian and I.S. Johnsrude and C. D. Good and J. Ashburner and R.S.J. Frackowiak and C.D. Frith. 2000. “Navigation-Related Structural Change in the Hippocampi of Taxi Drivers.” *PNAS*, 97 (8): 4398–4403.

Mandelbrot, B. 1963. "The variation of certain speculative prices". Journal of Business 36 (4): 394–419. *doi*:*10.1086/*294632.

Mansfield, E. 1991. “Academic Research and Industrial Innovation”. University of Illinois at Urbana-Champaign, USA

McCabe, M.J. 2004. “Information Goods and Endogenous Pricing Strategies: The Case of Academic Journals,” *Economics Bulletin* 12 (10), pp. 1-11.

McCulloch, A. 2015. Interview in magazine on May 21, 2015. *Publisher Now?*

ALPSP, Shoreham-by-Sea, West Sussex, UK: Association of Learned and Professional Society Publishers.

McCullagh, D. 2010. "Why nobody cares about privacy anymore". See http://www.cnet.com/uk/news/why-noone-cares-about-privacy-anymore.

McLuhan, M. 1964. "*Understanding Media: The Extensions of Man"*. New York: Mentor. 1964. Reissued Cambridge, Massachusetts: 1994, MIT Press. 1994

Mendeley. 2012. "Global Research Report". Mendeley Blog. 2012. Accessed September 25, 2015 http://blog.mendeley.com/academic-life/mendeley-has-two-million-users-to-celebrate-were-releasing-the-global-research-report/

McGuigan, G. and R. Russell. 2008. "The Business of Academic Publishing: A Strategic Analysis of the Academic Journal Publishing Industry and its Impact on the Future of Scientific Publishing." *E-JASL: The Electronic Journal of the Academic and Special Librarianship*. 9 (3) Accessed April 2014. http://southernlibrarianship.icaap.org/content/v09n03/mcguigan_g01.html

Microsoft. 2010. "Global CIO: Microsoft Pushes BI For The Masses: 500 Million Prospects". *Information Week*, April, 2010. Accessed September 25, 2015. http://www.informationweek.com/it-leadership/global-cio-microsoft-pushes-bi-for-the-masses-500-million-prospects/d/d-id/1088130?

Monbiot, G. 2011. "Academic Publishers Make Murdoch Look Like a Socialist: Academic Publishers Charge Vast Fees to Access Research Paid for by Us. Down with the Knowledge Monopoly Racketeers." And . "The Lairds of Learning – How Did Publishers Acquire These Feudal Powers*?" The Guardian* 29 August 2011. Accessed September 25, 2015. http://www.theguardian.com/commentisfree/2011/aug/29/academic-publishers-murdoch-socialist.

Moore, G.E. 1965. "Cramming More Components onto Integrated Circuits*." Electronics Magazine* 38 (8): 114-117

Morris, S. 2009. "Journal Authors' Rights: Perception and Reality, Summary Paper 5." London: Publishing Research Consortium

Morville, P. 2011. *Ambient Findability – What We Find Changes Who We Become*. Sebastopol, CA, USA: O'Reilly Media.

Mounce, R. 2012. GOAL listserv. 9 November, 2012.

Mumford, L. 1974. “Enough energy for life and the next transformation of Man” MIT lecture transcript. *CoEvolution Quarterly*. (4): 19-23. Sausalito, CA: POINT Foundation

Muramatsu, J. and W. Pratt. 2001. “Transparent Queries : investigation users mental models of search engines”. *Proceedings of the 24th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval.* ACM Press. P217-224.

Murray Rust, P. 2012a. GOAL Listserv. 10 August, 2012.

Murray Rust, P. 2012b. LibLicence. 2012.

Murray Rust, P. 2014. Blog dated February 2014.

Neilsen, M. 2009. “Is Scientific Publishing about to be Disrupted?” Neilsen Blog. Accessed September 25, 2015. http://michaelnielsen.org/blog/is-scientific-publishing-about-to-be-disrupted/

Neilsen, M. 2011. *Reinventing Discovery: The New Era of Networked Science*. Princeton, NJ, USA: Princeton University Press.

Neuendorf, K A. 2002. “The content analysis guidebook”. Online available. Accessed 10 October 2015 at: academic.csuohio.edu/neuendorf_ka/content/toc.pdf

Newton, I. 1668. *The Mathematical Papers of Isaac Newton – 1667-1670*. Cambridge, UK: Cambridge University Press.

Nicholas, D. 2010a. “The Virtual Scholar: The Hard and Evidential Truth.” *Digital Library Futures,* 23-32. Munich, Germany: K.G. Saur Verlag.

Nicholas, D. 2010b. “The Behaviour of the Researcher of the Future (the ‘Google Generation’*).” Art Libraries Journal* 35 (1): 18-21

Nicholas, D. and D. Clark 2013a. “Information seeking behaviour and usage on a multi-media platform: case study Europeana” *Progress and Research in Library and Information Study*. Springer, Winter, 2013.

Nicholas, D. and D.Clark. 2013b. “Information on the Go: A Case Study of Europeana Mobile Users”. *Journal of the American Society for Information Science and Technology*, 64(7): 1311-1322. 2013

Nicholas, D and D.Clark. 2013c. “Social Media Referrals on a Multi-media Platform: a case study of Europeana”. *Journal of Documentation, Information & Knowledge*. 2013, 0(6): 9-22.

Nicholas, D. and D. Clark and H.R. Jamili and A. Watkinson. 2014a. "Log Usage Analysis: What it Discloses about Use, Information Seeking and Trustworthiness". *International Journal of Knowledge Content Development & Technology* - Vol. 4 , No.1. Accessed September 25, 2015. http://ijkcdt.net/_common/do.php?a=full&b=12&bidx=193&aidx=2309

Nicholas, D. 2014b. "The Google generation, the mobile phone and the 'library' of the future: Implications for society, governments and libraries". A. Noorhidawati et al. (Eds). *ICOLIS-2014,*-Kuala Lumpur:-DLIS,-FCSIT,- 2014:-pp 1-8

NSF. 2007. "Cyberinfrastructure Vision for 21st Century Discovery", March 2007. Arlington, VA, USA: National Science Board. 2007.

NSF. 2010a. "Key Science and Engineering Indicators". 2010. Arlington, VA, USA: National Science Board.

NSF. 2010b. "Globalisation of Science and Engineering Research. A Companion to Science and Engineering Indicators 2010". 2010. Arlington, VA, USA: National Science Board. 2010.

NSF. 2014. "Key Science and Engineering Indicators". 2014. 2010. Arlington, VA, USA: National Science Board.

Nurse , P. 2011. Horizon tv broadcast. January 2011. Director UKCMRI and Royal Society.

OCLC. 2012. "Libraries: A Snapshot of Priorities and Perspectives". 2012. Columbus, OH, USA: Accessed September 25, 2015. http://www.oclc.org/content/dam/oclc/reports/us-libraries/214758usb-A-Snapshot-of-Priorities-and-Perspectives.pdf

ONS. 2010. "U.K. Gross Domestic Expenditure on Research and Development 2008". *Statistical Bulletin*. March 2010. London: Office of National Statistics

ONS. 2011. "Labour Force Survey". London: Office of National Statistics, LFS Data Service.

ONS. 2014. "Labour Market Profile". London: Office of National Statistics. Accessed September 25, 2015. http://www.nomisweb.co.uk/reports/lmp/gor/2092957698/report.aspx#defs

ONS. 2014. "Skills and Employment Survey, 2012". 2014. London: Office of National Statistics

OECD. 2008. "Science, Technology and Industry Outlook". Paris, France: Organisation for Economic Cooperation and Development

OECD. 2015. "Main Science and Technology Indicators Vol 2014/2". 2015. Paris, France: Organisation for Economic Cooperation and Development

Ofcom. 2014. "Communications Market Report: Converging Communications Markets", London, UK: Ofcom.

Ofcom. 2015. "Communications Market Report" London, UK: Ofcom: August 2015.

Outsell. 2009a. "Information Industry Market Size and Forecast Report". Outsell, Inc. Burlingame, CA, USA: Accessed September 25, 2015. www.outsellinc. com

Outsell. 2009b. "How researchers secure access to licensed content not immediately available to them. Research Report 1". For Research Information Network (RIN). Outsell, Inc. Burlingame, CA. USA. December, 2009.

Outsell. 2011. "Scientific, Technical & Medical Information: 2011 Market Forecast and Trends Report". November 22, 2011. Outsell, Inc. Burlingame, CA, USA: M. Ware for Outsell Inc. USA.

Outsell. 2013. "Open Access: Market Size, Share, Forecast, and Trends", Outsell, Inc. Burlingame, CA, USA: Outsell Inc. Accessed September 25, 2015. www.outsellinc.com.

Padley, R. 2014. "Wake up to what the 'article of the future' is really all about." Semantico, blog. Accessed September 25, 2015. http://www.semantico.com/2014/03/

Park, W. 2009. "The Publishing World is Open, Not Flat." *Learned Publishing,* 23 (4): 326-328.

PEER. 2012b. "PEER Behavioural Research: Authors and Users vis-a-vis Journals and Repositories". 2012. Loughborough: LISU and Loughborough University.

Pew Research. 2008. "Degrees of Access". S.Fox and J.Vitak. May 2008. The Pew Research Center's Internet & American Life Project, Washington, DC: Pew Research

Pew Research. 2012. "Digital Differences". K Zickuhr and A Smith. April 13, 2012. The Pew Research Center's Internet & American Life Project. Washington, DC: Pew Research

Pickard, A. J. 2013. *Research Methods in Information*. (2nd edition). London: Facet Publishing.

Plutchak, T.S. 2007. "What's a Serial when You're Running on Internet Time?" *The Serials Librarian* 52 (1-2): 79-90.

Polanyi, M. 1962. "The Republic of Science – Its Political and Economic Theory." *Minerva,* 1:54-74.

Porat, M.U. 1977. *The Information Economy: Definition and Measurement.* Washington D.C: Office of Telecommunications.

Poynder, R. 2011a. "Interview with Derk Haank" *Information Today*, January 14, 2011

Poynder, R. 2012b. "Reed Elsevier: A Short History of Two Days in July (and Why Investors Should Care)". Interview with C. Aspesi, Bernstein Research. 2012.

Poynder, R. 2014. "Interview with Jean-Gabriel Bankier, President and CEO, bepress" in *Open and Shut*, April 2014. Accessed September 25, 2015. http://poynder.blogspot.co.uk/2014/04/interview-with-jean-gabriel-bankier.html

Prensky, M. 2001. "Digital Natives. Digital Immigrants: Part 1". On the Horizon, 9, 1-6 . doi: 10.1108/10748120110424816;

Price, de S D. 1963. *Little Science, Big Science*. New York: Columbia University Press

Price, R. 2011. "The number of academics and graduate students in the world".". Blog dated 15 November 2011. Accessed September 25, 2015. http://www.richardprice.io/post/12855561694/the-number-of-academics

Pullinger, D. and C. Baldwin. 2002. "The SuperJournal Project – Electronic Journals and User Behaviour*"*. London: British Library R&D report, No. 61: 2002.

Ramesh, H. T. 2012. "The Information Opportunity Report - Harnessing Information to Enhance Business". Capgemini, Head of Information Exploitation, London.

Ramlogan, R. and L.A. Tedd. 2006. "Use and non-use of electronic information sources by undergraduates at the University of West Indies". *Online Information Review* 30 (1): 24-42 (2006).

RCUK. 2014. Press release dated 24 April, 2014.

Read, M. 2011. "Open Access for UK Research – JISC's contributions". Jisc. 2011.

Rightscom. 2005. "Disciplinary Differences: some findings and conclusions". (See Sparks 2005).

Rightscom. 2009. “Overcoming Barriers: Access to Research Information Content.” London: Research Information Network. 2009.

RIN. 2011. “Access to Scholarly Content: Gaps and Barriers”. (see Rowlands, 2011)

RIN. 2012. “Accessibility, Sustainability, Excellence: How to Expand Access to Research Publications. Report of the Working Group on Expanding Access to Published Research Findings”. [The ‘Finch Report’] Accessed September 25, 2015. http://www.researchinfonet.org/wp-content/uploads/2012/06/Finch-Group-report-FINAL-VERSION.pdf

ROAR. 2015. Registry of Open Access Repositories. University of Southampton, School of Electronics and Computer Science. 2003.

Rosenbaum, S.E. and C. Glenton and J. Cracknell. 2008. “User Experiences of Evidence-Based Online Resources for Health Professionals: User Testing of *The Cochrane Library.” BMC Medical Informatics and Decision Making.* 2008, 8:34. Accessed September 25, 2015. http://www.biomedcentral.com/1472-6947/8/34

Rowlands, I. and D. Nicholas and P. Williams and P. Huntington and M. Fieldhouse and B. Gunter and R. Withey and H. Jamali and T. Dobrowolski and C. Tenopir. 2008. “The Google generation: the information behaviour of the researcher of the future”. *Aslib Proceedings* 60 (4), 2008: 290-310

Rowlands, I. and D. Nicholas and P. Williams and D. Clark. 2010. “Google Generation Research: A Report.” CIBER Research London: British Library.

Rowlands, I. and D, Nicholas. 2011. “Access to Scientific Content: Gaps and Barriers.” CIBER, University College London, London: Research Information Network. Accessed September 25, 2015. http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCYQFjAA&url=http%3A%2F%2Fwww.rin.ac.uk%2Fsystem%2Ffiles%2Fattachments%2Fgaps_final_report_low_res.pdf&ei=grBkVeS9IYK1Ucv4gMAE&usg=AFQjCNHeleFLeTE8qpajMQbaHcmAJNoM7A&bvm=bv.93990622,d.d24

Royal College of Nursing. 2007. “Information needs of Nurses: summary report of an RCN survey”. 2 October 2007. London: http://www.rcn.org.uk/data/assets/pdf

Royal Society. 2010. “The Scientific Century”. See Taylor M, 2010.

Russell, N. 2014. Cornell University Faculty Library Board. Faculty Senate Meeting. March 2014.

Scohnfeld, E. 2009. Eric Schmidt tells Charlie Rose Google is 'unlikely' to buy Twitter. Retrieved from http://techcrunch.com/2009/03/07.

SCONUL. 2006. Society of College, National and University Libraries. London: sconul.ac.uk

Shaw, G.B.. 1954. "The Doctor's Dilema".

Shieber, S. 2013, Harvard University Office of Scientific Communications (See Harvard University, 2012)

Shirky, C. 2008. *Here Comes Everybody - How Change Happens when People Come Together*. New York: Penguin Books.

Shirky, C. 2010. *Cognitive Surplus: Creativity and Generosity in a Connected Age.* New York: Penguin Books, 2010.

Shonfeld, R. 2015. *Scholarly Kitchen.* July 2015.

Sloan, B. 2007. "Looming threat to Society Journals". 23 November, 2006. Liblicence.crl.edu.

Small, H. 2006. "Tracking and Predicting Growth Areas in Science." *Scientometrics* 68 (3): 595-610.

Smith, A. 1776. *An Inquiry into the Nature and Causes of the Wealth of Nations.* Published by Strahan and T Cadell, The Strand, London. 1776.

Smith, D. 2013. "What is Kudos? An Interview with David Sommers, Co-founder", *Scholarly Kitchen*. December 17, 2013.

Solomon, D.J., B-C Bjork. 2012. "A study of open access journals using article processing charges". *Journal of the American Society for Information Science and Technology.* 63 (8): 1485-1495. August, 2012.

Sonnewald, D. H. 2003. "Expectations for a scientific collaboratory: A case study", *Proceedings of the 2003 international ACM SIGGROUP conference on supporting group work*, 68-74, New York: ACM Press.

Sparks, S. 2005. "JISC Disciplinary Differences Report". London: Rightscom Ltd. Accessed September 25, 2015. http://www.webarchive.org.uk/wayback/archive/20080925114430/http://www.jisc.ac.uk/media/documents/themes/infoenvironment/disciplinarydifferencesneeds.pdf

Statistica. 2015. 'Statistica - The Statistical Portal'. Accessed September 25, 2015. www.statistica.com.

Suber, P. 2012. *Open Access*. Cambridge, MA: MIT Press.

Suber, P. and A. Page. 2013. "Societies and Open Access Research". Harvard Open Access Project (HOAP). cyber-law.harvard.edu.

Surowiecki, J. 2004. *The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*. London and New York: Doubleday.

Susskind, R. and D. Susskind. 2015. "*The Future of the Professions - How technology will transform the work of human experts"*. Oxford, UK: Oxford University Press. 2015.

Swan, A. 1999. "What Authors Want: The ALPSP Research Study on the Motivations and Concerns of Contributors to Learned Journals." *Learned Publishing*, 12 (3), 17-172.

Swan, A. and S. Brown. 2003. "Authors and Electronic Publishing: What Authors Want from the New Technology." *Learned Publishing,* 16 (1), 28-33.

Swan A and S Brown. 2007. "Researchers' use of academic libraries and their services – a report commissioned by the Research Information Network and the Consortium of Research Libraries". Key Perspectives Ltd. April, 2007.

Swoger, B. 2014. "Does the scientific journal have a future?" *Scientific American*. 18 June 2014

Tamir, D. I. and J.P.Mitchell. 2012. Disclosing information about the self is intrinsically rewarding. *PNAS.* 109 (21) pp 8038-8043.

Tapscott, D. 1998. *Growing Up Digital: The Rise of the Net Generation. New York:* McGraw-Hill.

Tapscott, D. and A.D.Williams. 2006. *Wikinomics – How Mass Collaboration Changes Everything*. New York: Portfolio.

Tapscott, D. 2008 *Grown up Digital: How the Net Generation is Changing Your World*. New York, NYC: McGraw-Hill

Taylor, M. 2010. "The Scientific Century: securing our future prosperity". Advisory group for The Royal Society. Sir Martin Taylor. London: RS Policy Document 02/10. March 2010.

TBI Communications. 2014. "Learned Society Attitudes towards Open Access*"*. May 2014. London: EDP. Accessed September 25, 2015. http://www.edp-open.org/images/stories/doc/EDP_Society_Survey_May_2014_FINAL.pdf

Tenopir, C. and D.W.King. 2000**.** ***"****Towards Electronic Journals: Realities for Scientists, Librarians, and Publishers"*. Washington, D.C: Special Libraries Association, 2000.

Tenopir, C. and D.W. King. 2004. *"Communication Patterns of Engineers".* New York: IEEE Press, Wiley Interscience.

Tenopir, C. and D.W. King and M.T. Clark and K. Na and X. Zhou. 2007. "Journal Reading Patterns and Preferences of Pediatricians". *Journal of the Medical Library Association* [Internet] 2007; 95 (1): 56-63.

Tenopir, C., D.W. King, S.Edwards and L. Wu. 2009. "Electronic Journals and Changes in Scholarly Article Seeking and Reading Patterns*." Aslib Proceedings: New Information Perspectives,* 61 (1) February 2009: 5-32.

Tenopir, C. and D. Nicholas et al. 2014. "Study on How Researchers Assign and Calibrate Authority". Funded by Sloan Foundation, February 2014. New York: USA,

Times Business Dashboard. 2011. November 30, 2011.

Toffler, A. 1970. *Future Shock.* Random House, USA: 1970

Tracz, V. 2014. "Open Science is the next step on from Open Access", Youtube presentation. 9 July 2014. www.youtube.com/watch?v=ONuMkf5zqg

UCL "Code of Conduct" and "Statement of Research Integrity". University College London. Gower Street, London

UKDBIS. 2009. "The Sectoral Distribution of R&D, 2009 Scoreboard." UK Department of Business, Innovation & Skills. London: UKDBIS. 2009.

UKDBIS. 2011. "Innovation and Research Strategy for Growth." UK Department of Business, Innovation & Skills. London: UKDBIS. 2011.

UKOFT. 2002. "The Market for Scientific, Technical and Medical Journals - A Statement by the OFT". UK Office of Fair Trading. London: Office for Fair Trading.

UK House of Commons, Science and Technology Committee, Select Committee of Enquiry on Scientific Publications. 2004. "Scientific Publications: Free for all?" Tenth Report of Session 2003-04. Accessed September 25, 2015. http://www.publications.parliament.uk/pa/cm200304/cmselect/cmsctech/399/399.pdf

UKMRS. 2014. "National Readership Survey – Social Grades", UK Market Research Society, London W1W 8AG, UK

Unesco. 2010. "*UNESCO Science Report 2010 – The Current Status of Science around the World"*. United Nations Educational, Science and Cultural Organisation. Paris, France: Unesco Publishing.

Unesco. 2015. "*Unesco Science Report – Towards 2030*". United Nations Educational, Scientific and Cultural Organization 7, place de Fontenoy, 75352 Paris 07 SP, France: Unesco Publishing,

University of California, Davis and California Digital Library, 2016, *"Pay it Forward*". July 2016. USA: University of California.

Univ Edinburgh. 2009. *Patterns of Information Use and Exchange: Case Studies of Researchers in the Life Sciences*. 2009. University of Edinburgh, Institute for the Study of Science, Technology and Innovation and the Digital Curation Centre. London: Research Information Network.

Varian, H. 2000. "Versioning: The Smart Way to Sell Information". In *Markets of One.* Ed James Gilmore and Joseph Pine (2000) 134.

Velterop, J. 2012. "The triumph of cloud cuckoo land over reality?". Blog dated Wednesday August 1, 2012. Accessed 5 May, 2016. Theparachute.blogspot.co.uk website.

Velterop, J. 2014. 'What is holding back the transition to open access if it does not cost more?' blog.scielo.org/en/2015/09/10/what-is-holding-back-the-transition. November 2014

Wallace, J.M. 2011."PEER: green open access insight and evidence" *Learned Publishing*. Vol 24, No 4. doi:10.1087/20110404

Ware, M. 2005. "Online submission and peer review systems". Bristol: Mark Ware Consulting.

Ware, M. and M. Mabe. 2009a. "The STM Report - An Overview of Scientific and Scientific Journal Publishing". 2009. The Hague, the Netherlands: International Association of STM Publishers.

Ware, M. 2009b. "Access by UK Small and Medium-Sized Enterprises to Professional and Academic Information". 2009. Ware Research. London: Publishing Research Consortium.

Ware, M. 2012a. “Scientific, Technical and Medical Information: 2012 Final Market Size and Share Report.” Outsell Inc. Accessed September 25, 2015. http://www.outsellinc.com/store/products/1107-scientific-technical-medical-information-2012-market-size-share-forecast-and-trend-report.

Ware, M. and M. Mabe. 2012b. “The STM Report - An Overview of Scientific and Scientific Journal Publishing*”.* 3rd Edition. The Hague: International Association of STM Publishers.

Ware, M. And M. Mabe. 2015. “The STEM Report -- An Overview of Scientific and Scientific Journal Publishing - 4th edition”. 2015. The Hague, the Netherlands: International Association of STM Publishers. March 2015 (updated November 2015)

Webster, F. 2014. “*Theories of the Information Society” (Fourth Edition)*. Oxford: Routledge.

Weinberger, D. 2007. *Everything is Miscellaneous: The Power of the New Digital Disorder*. New York: Times Books, Henry Holt and Company. 2007.

Weinberger D. 2012. *Too Big to Know: Rethinking Knowledge Now that the Facts Aren't the Facts, Experts are Everywhere, and the Smartest Person in the Room is the Room*. New York, NYC: Basic Books. 2012.

Wellcome Trust. 2008a. “Position Statement in Support of Open and Unrestricted Access to Published Research”. Accessed September 25, 2015 http://www.wellcome.ac.uk/about-us/policy/spotlight-issues/open-access/policy/index.htm

Wellcome Trust. 2008b. “Grant Conditions and Authors' Guide and FAQ*”*. Accessed December 2009. http://www.wellcome.ac.uk/stellent/groups/corporatesite/@sf_central_grants_admin/documen

Weller, M. 2011. *The Digital Scholar: How Technology is Transforming Scientific Practice*. 2011. London: Bloomsbury Academic

Weller, M.J., and J. Dalziel. 2007. “Bridging the Gap between Web 2.0 and Higher Education.” In-Handbook of Research on Social Software and Developing Community Ontologies, edited by S. Hatzipanagos and S. Warburton. IGI.

White, M.D. and E.E. Marsh. 2006. “Content analysis: a flexible methodology”. *Library Trends,* 55 (1), 22-46.

Wikoff, K. 2015. Liblisence listserv. 17 July 2015 by Karen Wikoff, Ithica, USA

Willetts, D. 2013. “We cannot afford to keep research locked away in ivory towers: opening up British research may seem obvious”. *Guardian.* 9 April, 2013.

Wilson, J.Q. 1989. *Bureaucracy: What Government Agencies Do and Why They Do it.* 1989. New York, NYC: Basic Books Classics.

Wulf, W. 1989. The National Laboratory in *Towards a National Laboratory*. Unpublished report of the National Science Foundation invitational workshop. Rockefeller University. New York.

Zudilova-Seinstra E. 2013. “Designing the Article of the Future”. Elsevier Connect. Posted on 16 January 2013.

10.2. ACRONYMS

AAP/PSP	American Association of Publishers, Professional/Scholarly Publishing Division (AAP/PSP) based in New York.
AAAS	American Association for the Advancement of Science. AAAS is the world's largest general scientific membership organisation with a stated mission of "advancing science and serving society".
AHRC	Arts and Humanities Research Council.
A&I	Abstract and Indexing services. Bibliographic databases of secondary information; metadata pointing to the existence of fulltext.
ALPSP	Association of Learned and Professional Society Publishers. Aims to serve, represent and strengthen the community of scholarly publishers. Has 315 members from 39 countries though has strong UK representation.
APC	Article Processing Charges. The price set for authors to have their articles published through open access.
API	Application programming interface. It is a set of routines, protocols, and tools to enable software applications to be built.
ARL	Association of Research Libraries. Non-profit organisation serving the largest research and university libraries in the USA and Canada.
arXiv	A subject based repository of digital manuscripts mainly covering areas in physics but with extensions into mathematics and computer sciences.
BIDS	Bath Information and Data Services, from University of Bath. Formerly provider of bibliographic services to UKHE, since morphed into Ingenta and then Publishing Technology plc.
BIS	U.K. government department responsible for Business, Innovation and Skills. See: https://www.gov.uk/.
BL	The British Library.
BRIC	Brazil, Russia, India and China. Rapidly developing global economies which are increasing their role in scientific

publishing.

BYOD	Bring your own device. Refers to the policy of permitting employees to bring personally owned mobile devices (laptops, tablets, and smart phones) to their workplace.
CC BY/NC/ND	Creative Commons licences for use of published material. BY = give appropriate credit for published work; NC = use can be made for non-commercial use only; ND = derivates of work not possible.
CERN	Conseil Européen pour la Recherche Nucléaire or European Organisation for Nuclear Research. Research organisation that operates the largest particle physics laboratory in the world. Established in 1954.
CHORUS	CHORUS is a suite of services and best practices that provides a sustainable solution for agencies and publishers to deliver public access to published articles reporting on funded research in the United States. Powered by CrossRef's service.
CIBER	CIBER Research Ltd, an independent research unit formerly part of City University and University College London. Headed by professor David Nicholas.
CREATIVE COMMONS	Legal framework developed by US attorney Lawrence Lessig in 2001 to enable authors to determine how much of their intellectual property they would like to control in allowing their research articles to be published.
CUDOS	Communication-Universalism-Disinterestedness-Organised-Sceptism, a concept developed by Merton (1968).
DIKW	Data-Information-Knowledge-Wisdom. Pyramid developed by Russell Ackoff (1989)
DOI	Digital Object Identifier. The DOI system provides a technical infratructure for the registration and use of persistent interoperable identifiers, called DOIs, for use on digital networks.
DRM	Digital Right Management. The intent with DRM is to control executing, viewing, copying, printing, and altering of works or devices unless permission is given by the rights owner.

ePub	*EPUB* is a free and open e-book standard by the International Digital Publishing Forum (IDPF).
FOIA	Freedom of Information Act in various countries. (2000 in UK).
GNP/GDP	Gross national product or gross domestic product, alternative ways of assessing the size of a nation's economy.
HEFCE	Higher Education Funding Council for England. Promotes and funds teaching and research in higher education institutions in England. Scotland, Wales and N Ireland have their own equivalents.
HEP	High energy physics, a research area with its own subject-based institutional repository (IR) – arXiv.
HESA	Higher Education Statistics Agency. Publishes data on student enrolments in U.K. including Destinations of Leavers from Higher Education. https://www.hesa.ac.uk/stats-dlhe.
html	HyperText Markup Language. The standard markup language used to create web pages.
IFLA	International Federation of Library Associations.
IT/ITC	Information Technology and Communications. Research discipline focusing on the application of technology in the communications process in particular (for this thesis)
ILL	Inter Library Loans. A service which enables libraries to borrow books from each other to meet occasional or regular loans requirements from requesting libraries.
IPA	International Publishers Association. IPA is a federation of national publisher associations representing book and journal publishing. It is a non-profit and non-governmental organisation, founded in 1896.
IPR/IP	Intellectual Property Rights. Ownership over goods/services produced.
IR	Institutional Repository. A repository of research output from an institution stored centrally and made freely available as part of Green Open Access movement.
Jisc	Joint Information Systems Committee. A United Kingdom non-departmental public registered charity which champions

	the use of digital technologies in UK education and research.
JSTOR	*JSTOR* is a digital library of academic journals, books, and primary sources. Part of the Ithaka group in USA.
LANL	Los Alamos National Laboratory. Los Alamos's mission is to solve national security challenges through application of scientific excellence.
Listserv	Listserv used to refer to a few early electronic mailing list software applications, allowing a sender to send one email to the list, and then transparently sending it on to the addresses of the subscribers to the list. One of a number of such services.
LISU	Library and Information Statistics Unit. A research an information unit based in the in the Centre for Information Management, part of the School of Business and Economics at Loughborough University.
M&A	Mergers and acquisitions. Growth policies pursued by companies to generate scale.
NESLI2	A Jisc Collections service which negotiates licensing contracts on behalf of university libraries in UK.
NetGen	(Inter)Net Generation – those who have been brought up to find their Information through online services.
njps	Non journal publishing systems. Focuses on alternative models for Disseminating research output.
NSF	National Science Foundation is an independent U.S. Government agency responsible for promoting science and engineering through research programmes and education projects. See: www.nsf.gov/.
OA	Open Access. A business model which stresses ‘free at the point of use’ for scholarly publications.
OECD	Organisation for Economic Cooperation and Development. Founded in 1961 OECD aims to stimulate economic progress and world trade. It consists of 34 member countries.
OAIG	UK Open Access Information Group. Supports exchange among Institutions of information about open access

	developments.
OINCS	'Out in the Cold'. Phrase used by British Library in referring to the UKWs in the 1980s/early 1990's.
OJS	Open Journal System (OJS) is a journal management and publishing system that has been developed by the Public Knowledge Project (PKP).
ONS	The Office for National Statistics (ONS) is the UK's largest independent producer of official statistics. Includes data on UK knowledge workers.
openDOAR	Directory of Open Access Repositories, run from University of Nottingham and funded by a number of international bodies, it lists open access repositories around the world.
ORCID	Open Researcher and Contributor ID is a non-proprietary alphanumeric code to uniquely identify scientific and other academic authors.
OSTP	Office of Science and Technology Policy. Congress established OSTP in 1976 with a mandate to advise the President and Executive Office on the effects of science and technology on domestic and international affairs.
MMR	Mixed methods research, part of methodology, a systematic way for giving a structured approach to research projects.
MOOCs	Massive Open Online Course (MOOC) aimed at unlimited participation and open access via the web on educational programmes. See en.wikipedia.org/wiki/.
OAPEN	Open Access Publishing in European Networks. The OAPEN Foundation is a non-profit foundation dedicated to Open Access publishing of academic books mainly in humanities and social sciences.
PA	Publishers Association. Represents all types of publishers, with the Academic and Professional division providing a forum for higher education, scholarly and reference publishers.
ppv	Pay-per-view. A business model which involves paying for online access to information, often focused on

	accessing articles on demand.
PRC	Publishing Research Consortium. A group of associations and publishers which supports research into global issues that impact scholarly communication. Funds occasional research projects.
PRISM	PRISM is a clandestine surveillance programme under which the United States National Security Agency (NSA) collects internet communications of foreign nationals from at least nine major US Internet companies. It was launched in 2007.
R&D	Research and Development. For this book's purposes, mainly in the natural sciences, biomedicine and engineering areas.
RAE	Research Assessment Exercise, the former (prior to 2014) national system for evaluating individuals and institutions based on metrics.
RCUK	Research Councils UK (RCUK), the strategic partnership of the UK's seven Research Councils (which includes AHRC, ESRC, BBSRC, etc).
REF	The Research Excellence Framework *(REF)* is the new system for assessing the quality of research in UK higher education institutions.
RIN	Research Information Network, a community interest company (CIC), formerly funded by U.K. funding agencies and headed by Dr Michael Jubb.
RLUK	Association serving 34 major Research Libraries in UK.
ROAR	Hosted by University of Southampton, ROAR (Registry of Open Access Repositories) is a Jisc-funded project within e-Prints project.
RSS	Rich Site Summary. Originally RDF Site Summary; often called Really Simple Syndication. Enables publishers to syndicate frequently updated publications.
RWA	Research Works Act. US bill introduced in 2011 to prevent federally-funded agencies introducing open access mandates for its research projects.
SCOAP3	SCOAP3 is the Sponsoring Consortium for Open Access

	Publishing in Particle Physics. It has converted key High-Energy Physics journals to Open Access at no cost for authors. SCOAP3 centrally pays publishers.
SCURL	Scottish Confederation of University and Research Libraries. Principal association of University and research libraries in Scotland and has been working collaboratively and cross-sectorally for over 30 years.
SDI	Selective Dissemination of Information. SDI refers to tools used to keep a user informed of new resources on specified topics. It predates the world wide web and has largely been overtaken by alerts, RSS feeds, etc.
SDSS	Sloan Digital Sky Survey, an astronomy project which attracts input from amateur scientists in order to catalogue the universe.
SEO	Search Engine Optimisation. Making sure that an information provider gets their publications listed as high as possible in a searcher's online enquiry.
SHARE	Shared Access to Research Ecosystem, an Association Research Libraries initiative, competitive with CHORUS from the publishing sector.
SHEDL	Scottish Higher Education Digital Library, through combined purchasing power, achieves a shared digital library in Scotland with easier access to online content for research
SMEs	Small and Medium Enterprises. Companies with up to 250 employees, many of whom may benefit from easy access to scientific information in support of their innovative activities
SPARC	The Scholarly Publishing and Academic Resources Coalition, of the Association of Research Libraries in U.S.A. - information on alternative scholarly communication strategies for research libraries. See www.sparc.arl.org/
STFC	The Science and Technology Facilities Council is a UK government body that carries out civil research in science and engineering, and funds UK research in

	areas including particle physics, nuclear physics, space science and astronomy.
STM	Scientific, technical, engineering and Medical research areas. Also stem or STEM. International Association of STM Publishers with offices in Oxford and the Hague. Represents over 120 members in 21 countries who each year collectively publish nearly 66% of all journal articles. CEO is currently Michael Mabe.
ToCs	Table of Contents.
UCAS	Universities Colleges and Universities Admissions Service. Central charitable organisation through which applications are processed for entry to higher education. Includes information and services for prospective students.
UCL	University College London.
UKWs	Unaffiliated Knowledge Workers. Those knowledge workers which would benefit from easy access to scientific information
UK	United Kingdom.
UKCMRI	The UK Centre for Medical Research and Innovation *(UKCMRI) is* re-named The Francis Crick Institute as from 2015.
UKOFT	UK government agency monitoring 'fair trading'. To ensure that corporate abuse was not occurring that consumer interests were protected. It closed April 2014 with its responsibilities passing to agencies such as Competition and Markets Authority (CMA) and Financial Conduct Authority.
UKOLN	UKOLN is no longer UK core funded (as from July 2013) but continues a more limited role in research data management and public engagement activities for a number of agencies at Univ Bath.
UNIGE	University of Geneva.
UNITAR	UNITAR is an autonomous body within the United Nations with a mandate to enhance the effectiveness of the UN through training and research.

USA	United States of America,
VISTA	Next emerging markets after BRIC which includes Vietnam, Indonesia, South Africa, Turkey and Argentina.
VoR	Version of Record. Final published paper available through the formal publication system.
WHEEL	Wales Higher Education Electronic Library, a national licensing scheme for higher education.
XML	Extensible Markup Language (XML) is a markup language that defines a set of rules for encoding documents in a format which is both human-readable and machine readable.

10.3. CASE STUDIES

10.3.1. Case Study – DeepDyve and document delivery

A template for a new approach to scientific publishing can be found in the activities of DeepDyve, a Sunnyvale, California, based organisation. A meeting was held with the chief executive of this organisation whose roots were in the Silicon Valley and whose start-up funding came from venture capitalists. This heritage is significant insofar as the traditional stakeholders in STEM – publishers and research librarians – were not instrumental in its initial development. It is a pioneer of an approach to the STEM environment, one which could result in a rethink of the aims and goals of concerned STEM commercial publishers in particular.

In addition to the meeting with the chief executive, William (Bill) Park, in August 2011, the company's strategic advisor (Joseph Esposito) was also in attendance. Esposito has made several pertinent comments in the past about the way STEM publishing has developed in recent years, and his views are included in this thesis.

Background

The DeepDyve operation is described in some detail as it encapsulates some of the background thinking which has led to this thesis. DeepDyve began operations in 2005. It spun out of a company called Infobel which had developed a search engine. Infobel has strong Chinese connections – some of the technical staff are based in China. However, it is essentially a Silicon Valley company with a physical location midway between Google and Yahoo! Though there is a Chinese connection, it is also understood that there is venture capital money and high profile angel investors behind DeepDyve which explains their frenetic activity since the formal launch of operations in October 2009. Park is one of the investors. In 2011/12 it was a small company of about 20-25 employees, 15 of whom are technical engineers, many of whom were working with cloud based technology.

Mission

DeepDyve's mission is to develop an additional market for research publications geared to the wider knowledge worker market. They have additional ambitions further down the track – for example, the search engine which was developed by Infobel is still being enhanced. Park made the distinction that Google is a locator; DeepDyve is more of a (vertical) search engine. Nevertheless, the visible side of DeepDyve is focused on article delivery.

The starting point for DeepDyve was that, as scientists and engineers, they were aware that library budgets are bad, and likely to get worse. STEM publishers would therefore be faced with a market squeeze, with one of their main recourses being to find new markets for published content. DeepDyve sets itself up as a partner with publishers to overcome the stringent market conditions facing existing products. Their solution was to make individual article ordering easier.

Operations

DeepDyve provides a catalogue to allow the new market – those who are not part of journal subscribing institutions – to find articles which they may want to 'rent'. Orders are placed against the catalogue entry. As such, sales of journal subscriptions or licences would not be compromised. Journal subscription sales and individual journal article sales would in theory coexist.

DeepDyve started its article rental service on 27 October 2009 with great expectations though with constrained financial resources. What DeepDyve offers is a rental service to allow access to publishers' articles at a price of $0.99, and that the income would be split equally with the relevant publisher. There are other pricing formulae – such as a monthly rental ($9.99), and there are special rates for those who make use of the service for the first time. But the 99 cents charge make DeepDyve the research publishers' equivalent of Apple's iTunes.

DeepDyve had some 30 million 'articles' in its catalogue. However, these articles were sourced from services such as the US Patents Office, WIPO, PubMed Central, Clinical Trials and all the 'open access' publishers such as PLoS and Hindawi. As such, although there is a strong emphasis on the provision of a service which provides cheap access to published articles for a viewing fee, there are also other media formats in the service. It means that part of the DeepDyve service is access to free and open access information. Given that we are entering a pluralistic society, where 'open access' and traditional subscription-based publishing coexists, DeepDyve can be said to be moving with the trends but not necessarily benefiting (in financial terms) from them**.**

Market potential

The company has estimated a market potential in the US of 50 million knowledge workers for their service. This was based on a 2006 US Census Bureau report, rather like this thesis' analysis of the UK's Office for National Statistics. However, DeepDyve did not drill down into viable sectors for scholarly articles, other than a reference to some statistics attributed to Michael Mabe (International STM Association) in 2009 '(Scholarly Publishing', in *European Review* 17 (1): 3-22) which suggested that there were some 35-40 million (of the 50 million) who were non-institutional knowledge workers.

Park also referred to an IDC report published in 2009 (International Data Corporation, 2009) which indicated that of US knowledge workers, 70% turn to the web first to conduct research, and in turn spend approximately 25 hours per month gathering information for both personal and professional purposes (IDC, 2009). So in theory there is a large latent market in the US for scholarly articles even if of questionable intensity. DeepDyve claims that in their discussions with publishers the estimated number of visitors to their site that were non-institutional visitors ranged from 35-60%.

DeepDyve is a one-stop-shop, independent, intermediary, which focuses on the end user and serving up everything from the most popular and relevant to the most arcane tip of the long-tail through a comprehensive, non-siloed service.

Constraints

However, it appears that the new market – the non-institutionalised users – is not ready for such a new service in sufficient numbers. DeepDyve does not know why this is – in theory the millions of knowledge workers should be trying to access the site and rent the articles they may or may not need for a limited and easy outlay. But it is not happening. Experience so far is that few people (non-subscribers) actually click onto the link. It appears that getting buy-in from the end users, selling the idea of a one-stop shop of easily accessible articles for a low rental price, has been difficult

Las with traditional infomediaries – the similarity between DeepDyve and subscription agencies/document delivery agencies is striking – journal publishers have not been supportive of organisations coming between them and purchasers (librarians). DeepDyve needs to convince not only knowledge workers that they have a useful service, but also publishers that there is a 'win-win', that there is a useful role which DeepDyve can fulfil which the publishers themselves cannot do. In effect DeepDyve's operations should not conflict with the revenue coming from subscriptions/licences and Big Deals. It appears that DeepDyve is not finding its middleman position that easy to get accepted by either publishers or end users.

In terms of getting buy-in from the publishers DeepDyve has focused on the large commercial publishers. Elsevier came on board with some 50 journals which it was testing to see whether the conversion rates for accessing the ScienceDirect site are better or worse than conversions coming from accessing DeepDyve's site for the same journals. Similar relationships were being finalised with Wiley for 30-50 journals. Emerald is also included and AIP has also included a system which raises a screen to link a non-subscriber of AIP titles to the DeepDyve site.

One of the contextual issues is the rise of author to author direct communications, the 'by-pass strategy'. Web 2 created the *Facebook, LinkedIn, Twitter*ing and blogging society in general and it could be these developments in wider society which could rub off on the research community and undermine the need for priced journals and articles. But Park suggests that there is little evidence of this having taken root. The 'article economy' remains healthy despite commercial challenges.

Usage

Park indicated that they are getting 100,000 accesses per month. When the service first started some two-thirds came from USA end users. Now (2012/13), two-thirds come from overseas. In the rank ordering of countries making use of accessing the DeepDyve rental catalogue, India is first, the UK second. This later amounts to about 6,000/7,000 accesses per month. (Other leading international markets include Germany, then China, then France). Nevertheless, there is little attempt so far to 'internationalise' the site. It is still driven by a US focus.

Surprising for such a venture capital/Silicon Valley based operation, they went into this with the assumption that if the service of article rental was offered, people outside the institutional market would want to make use of it. This is not the case, and even in those instances where articles were rented (and a special offer of three free accesses were made), little take-up of this offer has occurred. Two-thirds of those who accessed the DeepDyve site did not revisit it again within the next 90 days. The barrier is 'price', as identified by Ware in his research study for Publishing Research Consortium on SME's (Ware, 2009b), but more significantly by Anderson in his 'Free' book (Anderson, 2009b). Price, however low, remains the central feature of the DeepDyve concept. Although iTunes has shown that there is potential to get considerable end user buy-in from setting a very low price for an item, the problem is that however small the price it still represents a barrier to many users.

Studies

So why was the market research not done beforehand? Park felt that there was no other organisation trying this in the scholarly area. What makes him nervous is that 'first to market' or the pioneer is not always the most successful. There were no relevant reports available on which he could base the service – other than the Ware report on SMEs. So DeepDyve decided to take a risk and launch the service anyway.

Results

There are two issues – one is that DeepDyve underestimated the conservative nature of the STEM information sector. The second is related – that there is a window of opportunity which every new product/service goes through (see Gartner Hype Life Cycle) and that DeepDyve may be too early to benefit from the transition from a print-based business model to a digital environment with its different characteristics. A major transformation in user behaviour – particularly in such conservative audiences as scholars and researchers – cannot be realistically expected overnight**.**

Business plans

DeepDyve has nevertheless gone on record in estimating the overall size of a rental market for research articles at $2 billion. This compares with the Outsell/STM/Research & Markets estimates of the journal subscription business overall of around $8 billion. The estimate for the rental market seems excessively generous, but is based on market estimates derived from data provided by one publisher which indicated (in 2009) the following pay-per-view business for itself:

Traffic per year –	40 million visitors to the publisher site
% of the traffic which is non-institutional –	50%, which gives 20 million non-institutional visitors per annum
Current PPV sales of $1 million	Average article price being $25
This gives number of PPV transactions	40,000
The conversion rate is	0.2% (40,000 transactions from 20 million non-institutional visitors)
Number of non-institutional knowledge workers (estimated)	40 million

If this 40 million sign up for one article per month (at $0.99) the market size in the US is $480 million (or about $1.2 billion). If the 40 million sign up for the $9.99 per month the market size in the US is $4.8 billion (or about $12 billion).

As far as the above individual publisher is concerned, if the conversion rate were increased from 0.2% to, say, 4% through working with DeepDyve and establishing a link for the non-institutional customers to go to DeepDyve for a rental of articles, then the new income generated would be $800,000.

DeepDyve would split this $800k equally with the publisher. The publisher's new revenues of $400k would come without any conflict with the subscription/licensing revenues for the journals. In fact, if 5% of the non-institutional users then went on to buy the full article (rather than just renting it) from the publisher, the publisher would double its current PPV revenues to $2 million – again without cannibalising on its subscription revenues.

So the net gain to the publisher would be $400k in shared rental income plus an additional $1 million in facilitated extra PPV sales.

The Future

There are some key assets within the DeepDyve service:

- The power of the search software to search using long strings of search terms (better than Google)
- The inclusion of primary and secondary articles in a non-biased comprehensive and independent catalogue
- The ability to get payment per transaction (99 cents per view) which is shared equally with the publishers
- The protection afforded by the service to prevent downloads and copying of requested articles. Only a 24 hour viewing is allowed

Social media developments in society would still need to be monitored to see how they may impact on DeepDyve's one-stop business model in future. Their opinion is that scholarly communications is going to be built on the infrastructure of consumer publishing. This is because in a networked world the number of nodes connected to a network matter (Metcalfe's Law) and the consumer market has the big numbers. Scholarly needs will eventually be layered on top of a consumer infrastructure such as Google, iPhone, Twitter, etc.

Esposito was of the opinion that something much more fundamental than the web services is taking place – the adoption of digital consumer technology and having information delivered through the smart phones, e-book readers (Kindle, Sony), etc. These handheld devices were now driving a new demand through the provision of free or low priced apps. Smartphones may have a better potential for reaching the peripheral, non-institutional knowledge workers than the traditional formal carriers of books/journals even in a PC accessible format. Park mentioned that one of the technical developments they are working on is restructuring their software from Flash display to one which uses html/xml/ePub and can be delivered through iPads.

Summary

According to Park and Esposito, publishers will need to rely on new markets, such as the non-institutional knowledge workers, for its future income given that the library budgets will remain at least steady if not actually declining. This is the main point being made in this thesis.

Although in the past publishers have tried hard to disintermediate third party operations which come between publishers and the buying librarians in the case of reaching the broader end user markets there is a role for a new intermediary one-stop shop. A consortium of publishers with their respective silos could only offer access to a distorted and selective service.

The rental of articles is an inexpensive way for such knowledge workers to get access to information which might be of use in their private or professional lives. DeepDyve also includes a large element of 'free' and OA material as an added attraction to end users

The new market could create an additional income of up to 25% of the publishers' existing revenues. It does not cannibalise existing revenue streams.

However, DeepDyve needs to take on board that changing behaviour patterns, on this scale, is a long haul. Short-termism is not something which should be realistically entertained. Which raises questions whether DeepDyve has the financial resources to stay the course.

DeepDyve stands alone in pioneering this rental service. As far as they are aware nobody else – even the logical candidates such as Ebsco – are not moving in their area. Currently DeepDyve is focused on the US but it has global pretensions. Scale is an important issue which DeepDyve needs to consider.

Fundamentally, it is still not proven that the DeepDyve rental model is capable of taking hold within the non-institutional knowledge markets. It needs more market information/feedback and collaboration with existing stakeholders. However, it is a new project, conceived outside traditional stakeholders in STEM, which caters for the needs of a UKW audience. It is also a project which has greater affinity with trends in communications technology compared with traditional publishers and intermediaries.

10.3.2. Case Study: New forms of STEM information delivery

21 telephone interviews were conducted During 2012. These come from a cross section of academics in mainly information science and business areas in the UK and USA. The profile of the interviewees were:

- By discipline: 7 worked in the Business sector; 8 in LIS; 3 in social services; 3 in other subject fields
- By position: 5 were professors; 4 were lecturers or readers; 3 were researchers; 4 were librarians; 5 had other positions
- By country: 12 were located in England; 3 were in Scotland; 6 were in USA

Ten questions were asked over the phone. Interviews lasted on average 32 minutes. A semi-structured formal list of key questions was prepared. In several instances the experiences of the interviewees precluded their ability to respond with any value to some of the subsequent questions. In these instances their respective contexts and experiences were explored in a less structured, informal mode, to determine what barriers existed to their accessing information online.

Background

Twelve of the 21 contacted used social media to varying extents, but mainly for personal communications only. Only four had any significant experience with particular online STEM services. There were a couple of interviewees who had at best a passive involvement. Several people recognised that a single point of community contact offered some appeal but they were not there yet.

Acceptance of social media and online services by discipline

Discipline	Yes	Perhaps	No
LIS	4	1	3
Business		1	2
Industry	1	1	2
Sociology	1		2
Others	1		

Adoption of Social Media by status/position

Position	Yes	Partial	No
Librarian	3		1
Teachers (some LIS)	2		3
Researchers	2	1	
Combined (teach/res)			
Professors	1	1	2
Others	2	1	2

Independent studies corroborated the above – that a majority of researchers make occasional use of one or more Web.2 services for research purposes; for communicating research activity; for developing and sustaining networks and collaboration; or for finding out what others are doing. But frequent or intensive use is rare, and some researchers regard blogs, wikis and other novel forms of communication as a waste of time or prejudicial to their own research efforts. One contact made the point that blogs dry up once the blogger has finished airing all his/her ideas and prejudices.

Several interviewees mentioned that they use *Skype* to keep in touch with colleagues. In many respects blogs, wikis, lists, etc. are antithetical to the way researchers are trained – the whole point about social media is its spontaneity, getting one's ideas out in the open even at the risk of being wrong or incomplete. Traditional publishing has a long process of drafting, refereeing, editing – a tough jump from one to the other for many researchers to make.

Those interviewees who were at the cutting edge between the formal and informal communication systems emphasised the importance of the interpersonal contact as the basis for agreeing to enter into joint work. Personal introductions, conversations at meetings, or hearing someone present a paper are seen as key in developing collaboration. Successful researchers have established personal networks which have been built up from years of attending conferences.

- **Are you part of an online community – either active or passive? If so, which?**

Several interviewees thought that – in certain circumstances – social media and online communities are already available. One contact, an advisor on information sources in a UK university, claimed that there are already active communities in operation. These were outside the reach of the current formal journal publishing system and often built around Twitter tags, *Mendeley* and *FaceBook*.

Examples of the communities people belonged to include those run by the International Association of Ecology & Health, the British Sociological Association, Citehr and academia.edu. One contact was instrumental in advising students and postgraduates which combination of social media (Twitter and Facebook-based) would suit their particular needs.

- **Are there any scientific communities of which the researcher is aware that they have decided not to take part in – and why?**

Time constraints are a big factor in preventing most of the passive or non-partakers from engaging with an online community or portal but also from standing back and evaluating the benefits of being part of one. As such there were few instances among the 21 interviewees where there had been a conscious decision not to participate. Communities, which the interviewed were aware of but did not use, included NASAGA, Library 2.0, and web Junction.

A leading distraction claimed for Internet-based services is that they create excessive noise.

Nine of the 21 interviewees could be described as traditionalists bordering on dinosaurs. Two senior professors felt that they had no need to be part of a scientific online community as – over the years – they had developed rich personal networks of their own. Any communication would be among their preselected peers with whom they have vested trust and authority. However, another professor pointed out that there was a risk of becoming locked in to an incestuous dialogue, eliminating innovative ideas, in relying on a closed network. Some claim that older researchers have established networks on which they rely, whereas others suggest that the younger researchers also need to rely on traditional systems to gain acceptance from their peers and funders. In this case it is the established researchers which have the time to innovate and experiment without impacting on their career paths.

One of the younger interviewees felt that she was a ‘grubber’, and needed to be plugged into all available social media and communities to ensure that she was keeping up and was also able to create her own online persona. She felt that new ideas ‘lurked’ in left field areas.

Half the respondents felt they were busy enough without time distractions created in having to wade through mountains of (potentially) peripheral and spurious information. Those with primarily teaching activities in particular gave indication of having no time for, or not wanting to, experiment and innovate with new media in what was seen as a noisy area. One interviewee felt there was ten years to go before communities prevail.

Frequently mentioned was that the noise aspect could be overcome if a moderator took over the function of sifting through the various types of social media and social networks to present succinctly to the community those items which were seen as credible. It would require a new skill set which is not currently part of the scholarly publishing scene. This is particularly relevant for developing information support services for UKWs.

One interviewee cited the need for a ‘translation’ service to reach wider group of professions/SMEs and get their participation (see the Nautilus concept in section 6.4.11). Democratisation of STEM information was seen as being important by several contacts who felt that disclosure of their research results were being prevented by the current subscription model.

- **Open Access is frequently claimed to offer advantages which obviate the need for social networking and communities. Is this the case?**

Online communities require a combination of three aspects – digital content; networks and openness. Openness provides the stimulus for researchers to share, to be transparent and interactive without which online communities would be stale, sterile and at best one-way communication. Open systems are fundamental to the success in introducing new products or services which are innovative within the digital age.

Scholarly publishing is not new to openness – it has relied on free and open refereeing systems, free submission by authors, free editor's time and sometimes facilities – so extending the openness to building services around portals, hubs and online communities which are based on free and open interaction could be considered trivial. Only the seven LIS interviewees had any understanding of the role of Green, Gold and Hybrid OA has on scholarly publishing. And four others had some knowledge – the other nine contacts were unaware or totally confused by the open access debate, often because they had greater teaching rather than research roles. The principle of free-at-the-point of usage was accepted in principle, but how did this impact on the well-established quality assessment procedures? was frequently asked.

There were reservations about the quality, or more specifically, perceptions by others about the quality of open access. This attitude is important as a backdrop to the adoption of social media and the inclusion of easy access to knowledge workers – if free to access information services have a connotation of not being reliable or trustworthy then this could carry over to social media based services as well. Open access and social media are bedfellows.

- **Online communities offer the opportunity to break away from the 'elitist' and closed STEM (scientific, technical engineering and medical) publishing system serving research libraries, and open up discussion to a global community. Is this realistic?**

Several contacts recognised that the infrastructure for online scholarly communication – digital; networks and openness - was already in place (in the mass consumer market) and that this infrastructure would ultimately be transferred into the research communication sector as soon as the current 'reward system' for tenure, career progression and funding were modified to cope with more effective assessments of research output quality. Several of the more aware contacts – aware in the sense of seeing the grand picture for scholarly communication – volunteered the view that the current system of toll-based journal publishing is elitist and undemocratic.

Several contacts did favour a break away from the current elitist focus through an online community programme and recognised that there were several other sectors which were not being offered ease of access to required material.

One issue which emerged is whether a 'translation' is required to describe the same research output both for the elite in the field who would understand the technical jargon, and another version for the practitioners and others who would need a more descriptive and layman account to reach the great unwashed (see Allington, 2013).

One interviewee made the distinction between academics who support journals because they have become part of their DNA; from that outside academia who largely support social media. The two cultures need to coalesce.

- **Is there a role for the traditional commercial publisher in creating and maintaining online communities? Or are learned societies better equipped?**

Several interviewees thought that the best role for publishers was to speed up the publication cycle by offering a community built around a journal (online submission, editing, interactive refereeing). To focus on improving the current publication system by adopting social networking to reduce time and costs; to be more innovative with their repackaging of published content. Not just publishing abstracts but to make them more like management summaries. Also publishers should consider pre- and post-open refereeing.

Others volunteered that there is a role for an editorial manager to expand into running an informal bulletin board alongside the formal journal. Another recommendation was that there should be more alerts and easy linking to related publications. Offering free access to chapters; 'more like this', chat sections, etc, was also suggested. Still others claimed that long-term strategies should be set which tackles issues such as business plans, skill sets, content selection, product formatting, etc.

It was also felt that online communities could be established and run by individuals within the research community itself.

However, if a partnership is required one suggestion was to collaborate- with the relevant learned society which has the knowledge-base and client base to support an online community. Another interviewee made the point that no one individual could run an online community effectively. It requires a committee; it would take time. "Blogs would have to be followed; RSS feeds collected; bulletin boards looked at; trade journals scanned. No one person could do all this [and do a job at the same time]. Selection would be important.

Should a publisher become involved they would need to import the skills and knowledge base to work with the community in developing a balanced approach to dissemination of content, and stimulating interactivity, based on the many printed and social media sources available to the particular community concerned. (It would appear from the above that traditional editorial skills, of editorial planning, are not suitable for the new role of community moderator according to those interviewed).

However, there was one interviewee who was against the idea of traditional publishers becoming involved in developing online communities. The feeling was that publishers should concentrate on what they do well – making things as easy for authors with quality manuscripts to be published in an agreed format. They should not get involved in organising new user-focused information services because (a) timeliness would be affected; (b) additional protocols would have to introduced; and (c) the exclusivity of the (elitist) publishing system would be compromised.

- **Is there an acceptable business model which supports the creation of an online community?**

Online communities are usually free to access. How then can an organisation running a community remain viable? One of the interviewees made the point about returns on investment. The costs of developing a sophisticated infrastructure which protected security, applied authentication where necessary, coped with different input formats, standards, protocols – as well as introducing a skill set which provided for quality moderation – all this would be expensive and no guarantees exist that there is a budget available to sustain this system. Individual researchers would be unlikely to pay in this 'open' and 'free' Internet. Advertising may have to be consider even though this has adverse connotations.

On the other hand, the subscription model supplemented by a high priced PPV is not acceptable to those respondents who had a strong library background. But the concept of Free (Anderson, 2009b) looms large over any service which hopes to include social media and online communities. As Anderson's book shows, even the smallest price raises a barrier to use. And as the net generations grow accustom to free services, and as GoogleScholar offers a free discovery service which competes effectively with sophisticated online database services, the issue of how to recoup investment in a social media plus formal publication programme is a difficult one.

- **Is there anything else which is relevant to the future progression of communities within scholarly discourse?**

The dominant theme to emerge from the interviews was that publishers should focus on using social media technology to speed up the current publishing cycle. There was less support for them to move into new ventures such as online community creation and support where the skill sets required were not part of the publisher's armoury.

There may be a distinction between those contacts who were authors – and wanted publishers to concentrate on improving their existing services at the periphery, and those contacts as users who have greater inclination to adopt social media, online communities, etc. This distinction is worth exploring in further market research.

Also mentioned was that librarians could be recruited to be on board as gatekeepers between information sources and the users. Some universities, such as Warwick, UCL, etc, have in-house management information systems or Dashboards which could be linked into the community.