

Chapter X

Socio-scientific Issue-based Learning: Taking Off From STEPWISE

Ralph Levinson* and the PARRISE Consortium¹

Abstract In the European Union educational policy-making bodies are encouraging projects of inquiry-based learning to stimulate interest of young people in science and broaden the science and technological base. In this article I discuss how a project which incorporates socio-political questions as the object of its inquiry can critically address issues of consumerism and unequal distribution which affect contemporary neoliberal economies. Components of this model of inquiry draw on substantive scientific knowledge incorporating Responsible Research and Innovation (RRI), Critical Citizenship Education, Socio-Scientific Issues as well as Inquiry hence the acronym, SSIBL (Socio-Scientific Inquiry Based Learning). Social values at the heart of this project are science inquiry as *for* and *with* people recognising that we live in a diverse world where technological change should be underpinned by social justice and political responsibility. We describe how authentic activities, those which stem from students' concerns, can be derived from these values to lead to non-trivial action which takes into account social, political and cultural constraints and uncertainties. Inquiries reflect issues which have personal, social and global relevance. A sensitive assessment strategy is developed which incorporates knowledge about the issue, skills of organising, values that reflect the underlying principles of compassionate justice and dispositions of inclusivity and criticality.

Keywords Inquiry; Responsible Research & Innovation; Socio-Scientific Issues; Social Justice; Action; Authenticity.

Introduction

In the contemporary post-industrial world, where effects of neoliberalism and globalisation on education policy are becoming increasingly insidious (Ball, 2013), it is encouraging to see a resource such as STEPWISE², which explicitly challenges underpinning social values and epistemologies of school education encouraged by a market adapted for extreme consumerism. STEPWISE provides not only encouragement for socio-political engagement but a theoretical framework that justifies the strategies adopted. For reasons discussed in Chapter 2, it is challenging for the STEPWISE philosophy to gain leverage in science school curricula. Those situations where STEPWISE has gained momentum perhaps emphasize the exceptional characteristics of pedagogy and democratic school structures where such practice is enabled.

¹ Based on: Levinson, R. & The PARRISE consortium (2014). *Initial SSIBL framework*, D1.2 PARRISE, co-funded by the European Union under the 7th Framework Programme, Freudenthal Institute for Science and Mathematics Education, Utrecht, The Netherlands/ Institute of Education, University of London, United Kingdom.

² STEPWISE' is the acronym for Science & Technology Education Promoting Wellbeing for Individuals, Societies & Environments. It is a theoretical and practical framework that organizes teaching/learning goals in ways that encourage and enable students to self-direct research-informed and negotiated actions to address personal, social and environmental problems linked to fields of science and technology. To learn more about this framework, refer to chapter 2 in this book (and: www.stepwise.ca).

*R. Levinson, University College London Institute of Education, London, UK

Enacting the STEPWISE philosophy cannot separate itself from the broader educational and social context. Science curricula in most post-industrial countries have outcomes based on meeting certain defined targets and a teacher culture that is underpinned by ‘presentism’ (Hargreaves & Shirley, 2009), a persistent focus on short-term measurable outcomes.

The Political Climate

Schools and their curricula do not exist in a socio-political vacuum (Apple, 2004). Science curricula, and their associated STEM agendas, have been particularly susceptible to political influences (Pierce, 2015). This can be seen, for example, in the 2012 curriculum reforms by the UK conservative government, which imposed greater prescription and focus on content (Vasagar, 2012). Added to this are political pressures generated from international comparisons through the PISA results where England was seen to do badly compared with the Asian tiger economies. “‘England needs a rocket under them to improve their PISA scores’”, says Minister for Education” (Baird *et al.*, 2011, p. 140).

One of the reasons why there is such panic about achievement in STEM subjects can be seen in resources that privilege science, technology and engineering in higher education as well as in rhetoric that accompanies pushes towards the STEM agenda. Such rhetoric is couched in language of national economic competitiveness, human capital resource (Thomasian 2011), supply and demand, high-end technologies and added values — together with ‘softer’ language of climate change and sustainability (Ravetz, 2005). The new science-society formulation of the EU, however, is ‘RRI’ (Research, Responsibility and Innovation): emphasizes being on science *for* society and *with* society (Owen *et al.*, 2009). Advancements in science and technology need not be detrimental to the planet or to human communality; on the contrary, with public participation and goodwill, technoscientific progress in a market-driven economy could, according to RRI philosophy, go hand-in-hand with technologies that can remediate some of the more harmful effects to environments. Such proposals need to be treated with caution, however, particularly in light of dismantling of welfare state policies in Europe, rise of free marketism and entrepreneurship, as well as the complexity of relations of technical expertise and lay knowledge and concerns (Jasanoff, 2003).

No one except an extreme Luddite (in fact there is a lot we can learn about collective bargaining from the Luddite movement and the political organisation in response to the introduction of labour-saving technologies) would gainsay that technologies can be enhanced for the public good. For those of us, particularly those born between the end of WWII and the 1960s, who live in the post-industrial world in relative affluence and employment, benefits of a highly developed science and technology base are manifest in vastly improved health, longevity, mobility, educational possibilities compared with our grandparents. But the problem is not that science and social egalitarianism are mutually contradictory; i.e., that science and technology are associated with markets and free enterprise, as opposed to fair distribution of goods. Despite attempts to exploit possibilities of digital technologies, for example, to address social exclusion and enhance social mobility little progress has been made (Selwyn *et al.*, 2001). One of the problems is the nature of the consumer-led and driven market that creates goods which harm social life, and a hyper-reality (Baudrillard, 1994) that is self-referencing. Social and material inequalities reduce social trust and drive consumerism; there is a correlation, for example, between a country’s income inequality and low levels of waste recycling and high carbon emissions (Wilkinson & Pickett, 2010). When tracing back materials that give us so much value (e.g., superconductors, gems, rare metals) to their source (a problem addressed by STEPWISE), benefits of material progress for the affluent in rich countries need to be measured against material and social devastation caused to those in producer countries (Shiva, 2000).

*R. Levinson, University College London Institute of Education, London, UK

Over the last thirty years in the UK and much of the industrialised world, there have been shifts through the ‘Third Way’ (Giddens, 2008) towards more overt neoliberal discourses; the recent TTIP (Transatlantic Trade and Investment Partnership) agreements reflect the extent to which the EU treads carefully with global corporate giants. New information and social media technologies have accompanied these changes, which have also enhanced possibilities for, and economics of, globalisation. In terms of science, there have also been concomitant changes in the nature of citizenship, from one which was dependent on the goodwill of the state and scientific expertise to one which has become sceptical of expertise, and organising itself in new ways (Novas, 2006). STEPWISE’s response to this problem is to enhance social empowerment through school science education (Bencze & Carter, 2011).

Socio-Scientific Inquiry-Based learning (SSIBL)

In this article, I discuss a framework for a European project (EU) that is influenced by philosophy associated with STEPWISE, namely an aspiration to social justice through authentic action, but which builds up from inquiry and citizenship through the EU formulation of RRI.

SSIBL. The European Union has a broad commitment to Inquiry Based Science Education (IBSE) (Rocard, 2007). Inquiry-based methods have been shown to increase ‘both children’s interest and teachers’ willingness to teach sciences’ (p. 12). Much of IBSE funded by the EU to date has focused on developing scientific knowledge and procedures (in STEPWISE terms, Product and Skills Education) and has been broadly inductive. Pierce (2015) has described this separation of science from social and cultural concerns as ‘purification’ which stems from a broader Enlightenment problematic.

Socio-scientific inquiry is challenging for teachers because it takes students to unexpected and unanticipated areas of knowledge. Some of the inquiries discussed below are similar to the kinds of activities proposed by STEPWISE. I am part of a consortium of science teacher educators in universities in Europe, with the acronym PARRISE (Promoting Attainment of Responsible Research and Innovation in Science Education) funded by FP7 (‘FP7’ stands for the ‘7th Framework Programme for Research and Technological Development’ and is designed to respond to Europe’s needs in terms of jobs and competitiveness as well as enhancing the global knowledge economy).developing inquiry activities in the context of Research, Responsibility and Innovation (RRI), Citizenship Education (CE) and Socio-Scientific Issues (SSI) (see Figure 1).

<Figure 1 about here> [**RALPH: PLEASE ADD CAPTION**] <The components of SSIBL>

Our project acknowledges importance of social participation: scientific research and production should be carried out *with* and *for* society (Owen et al., 2009). How this can be achieved presents political and structural challenges (von Schomberg, 2013) through ‘anchor points’ that are ethically acceptable, sustainable and socially desirable. Influences of political literacy, i.e. critical citizenship education, on inquiry-based activities frame science inquiry within contexts of social and political questions, what we have termed SSIBL (Socio-Scientific Inquiry Based Learning). At the heart of SSIBL, is researching a question aimed at improving local and/or global conditions, producing realisable outcomes through democratic processes, and drawing on scientific knowledge that may be recontextualised as part of this process. The inquiries should stem from the concerns and pre-occupations of the young participants, although scholars such as Laurent Humbel *et al.* (2010) recognise that social inquiries stimulated by controversy need to incorporate a pedagogical triggering mechanism, an ‘element declancher’. Hence, part of the SSIBL programme at the scaffolding stage has much in common with apprenticeship activities in STEPWISE. In the next section, we describe some examples that reflect the spirit of SSIBL.

*R. Levinson, University College London Institute of Education, London, UK

What SSIBL activities might look like. Before depicting the SSIBL framework, below are a few examples to illustrate its philosophy.

Campaigning against the school's sugary drink dispenser

This account was given by a college principal and formed part of the evidence for the Valuable Lessons (Levinson & Turner, 2001) research study.

Senior management in a college for students in the 16-19 age range installed a drinks dispenser to raise money for extra-curricular activities. Noting the problem of a dispenser of high-sugared drinks in their college, a small group of students decided that the action by the school authorities was detrimental to the students' interests. Such drinks were deemed to be unhealthy and to inhibit concentration. They approached the Principal, asking for the dispenser to be withdrawn. The Principal refused, arguing that money raised by use of the dispenser helped to fund out-of-school activities and was used by many students.

The group then decided to collect as much secondary evidence as they could to buttress their argument and to campaign within the college for its removal. They brought their argument to the College Council, a representative student body, which decided that the dispenser was not in the college's best interests but to also form a group to find alternative ways to make good any losses incurred by the removal of the dispenser. The college management agreed to implement their decision and to work with them to find alternative ways to raise money.

Assisted Reproduction

This activity is based upon challenging representations of assisted reproduction (AR) often promoted by private clinics (Figure 2).

<Figure 2 here> **[RALPH: PLEASE ADD CAPTION]** <Use of images to promote raising questions>

Questions about AR are commonly-discussed in older age groups in secondary schools, aged 15+ . Young adults are reaching an age where having children becomes realisable and many values of family and status are related to having children. AR is a medical resource that can enable a couple to have children, but problems as presented in schools are often conceptualised as medical ones: the biology of the couple's reproductive systems, and associated psychological problems (Reis, 2015). But these raise other 'hidden' questions.

1. Should AR be publically funded through the health service. What is health? Does AR come under the category of health? In some countries, AR may be positively encouraged through public health services for political reasons; e.g., population growth. In others, it may be very difficult to gain access to them.
2. If AR is sought privately, this raises questions of social justice – a balancing of rights ('I have the right to spend my money to follow options open to me') as against egalitarianism and social cohesion ('why should advantages of embodied nature be available for some and not others?'). In a society where it is seen as desirable, or having status, to have children accessibility to this technology is, therefore, a political question. What about political, cultural and religious issues in extending these rights to same-sex couples?
3. Regulation of the fertility industry. Fertility clinics regularly advertise through media (see Figure 2). How they represent themselves is open to critique. But how are they regulated against malpractice?
4. That technologies are available makes it important to understand risks involved. What information would we need to assess these risks?
5. What about ethical questions implicit in AR? Such a technology effectively makes selection of particular attributes possible. The most common is sex selection but also selection against or

*R. Levinson, University College London Institute of Education, London, UK

sometimes for particular disabilities; e.g. there has been a debate in the deaf community about selecting *for* deaf children (Mand *et al.*, 2009).

6. Poorer countries have become suppliers of cheap womb labour and services; e.g., egg provision. Globalised economies, reproductive tourism. <http://www.eggsploitation.com/>

Hence, this raises questions at personal, social and global levels:

What does this mean for me and my family? How do I feel about the possibility of AR?

What do these questions mean for the society I live in?

What are the global issues connected with this? What are the practices now and how do they promote diversity and inclusivity, compassionate justice and renewal of life?

Figure 3 represents the inter-connected issues which arise from the above questions about AR and link the social and political questions to the scientific context.

An outcome of inquiry into this issue might be a leaflet produced by students which raises some of these questions, and suggested stimuli for discussion in science lessons.

<Figure 3 here> **[RALPH: PLEASE ADD CAPTION]** <Concept map – Assisted Reproduction>

School animal house

Studying heat transfer, the teacher might use a number of examples, including the school animal house. Pupils in a school might be aware that the animal house is quite old, and can become over-warm in summer and too cold in winter. As a result, in winter, the heating system has to be kept on to keep the animals warm and, in summer, the fan has often to be kept running to cool the animals. This extra use of electricity impacts on the school's electricity bills and pupils can relate this to excessive and unnecessary use of fossil fuels at a global level. They could draw on their knowledge of heat transfer to solve the problem and, as a class, generate the question: 'What is the best design for the school animal house?' It has to maintain a steady temperature (knowledge of small warm-blooded mammals) under different weather conditions. The planning stage might involve different groups testing different materials and designing small scale models to check their predictions. Each group designs their own model and tests how well they maintain a steady temperature in different ambient temperatures (high and low). Some time is allowed to change designs, if necessary, and then each group presents their findings to the year group. The best design is selected and the pupils build the animal house (or employ a company to build the house according to their plans). Tests are carried out once the animal house is built to check that it is working properly, and they also assess changes in fuel bills as a result of their design. The details of their inquiry are presented at the local teachers' science education meeting.

Table 1 outlines the age range, the scientific knowledge which needs to be recontextualised and applied for each inquiry activity and possible action points.

TABLE 1: CONSTITUENTS OF SSIBL ACTIVITIES

<Insert Table 1 here>

Explaining the framework

SSIBL is comprised of an overarching context, RRI, and three interconnected pillars: CE, SSI, IBSE underpinned by an engaged pedagogy (Figure 1). I discuss each of these, in turn, below.

RRI

Technological developments, inspired by research and innovation, both have an impact on, and are influenced by, social values and social change. Owen *et al.* (2012) identify three underpinning features of RRI:

- i. Science *for* Society (SfS),

*R. Levinson, University College London Institute of Education, London, UK

- ii. Science *with* Society (SwS), and
- iii. coupling of research and innovation with responsibility (R&R).

Science *for* society focuses on public values i.e. normative motivations; science *with* society on dialogue and deliberation; i.e., substantive motivations; and coupling of research and innovation with responsibility as a recognition of practices of science, uncertainties and risks associated with development of any technology and how these might be anticipated and managed (Ravetz, 2005).

Science *with* society is participative. This acknowledges that those affected by the technology, as well as scientists, can influence decisions both at the upstream stage (that is, when the scientific ideas are initiated and possible consequences anticipated) as well as downstream at the point of production, application and distribution. Participation and dialogue in research assume knowledge and understanding of the underlying science, as well as critical appreciation of processes of the research both in its scientific and social components. Participative R&D is, therefore, a multi-agency approach to research and innovation because knowledge is differentiated and distributed in form (i.e., from academic knowledge, including different disciplines, professional knowledge, knowledge-for-living) (Layton et al, 1993;). These foreshadow interactions between formal (curricular) and *informal* (non-curricular) knowledges.

In discussing values, people are identifying not only norms by which societies cohere but also those which are desirable. These can reflect a conflict between market-driven economies and needs for ethical relationships between people within a sustainable society. For example, drives for economic growth can potentially stimulate development of alternative technologies that support sustainability and zero carbon outputs. However, it can also endanger desirable outcomes because economic growth drives increasing levels of consumption; hence, the need for critical approaches that identify, problematise and raise questions about underpinning *values*. SfS is the process where science takes into consideration ‘the values, needs and expectations of society.’

(https://ec.europa.eu/programmes/horizon2020/sites/horizon2020/files/FactSheet_Science_with_and_for_Society.pdf)

Underpinning a curriculum and pedagogy that aims at enhancing human capacities within socio-cultural realities in which people live, Roger Simon (1992) derives three principles: *securing diversity, compassionate justice, renewal of life*.

<Insert Figure 4 here> [RALPH: PLEASE ADD CAPTION] < Relationships between RRI and socio-scientific inquiry>

Securing diversity assumes differences between people (and non-human species) from classrooms to the whole planet entailing an ethic of respect. This implies opening participation in classrooms to young people who are often prevented from fully engaging, and understanding that needs, interests and voices of people and communities across the world are mediated by power relations and have unequal status. Recognising diversity means inclusivity in terms of impacts science & technology have on a whole range of stakeholders, including those who cannot claim a stake for themselves but who are affected by impacts of the technology. It is an opportunity for disadvantaged groups to gain and use relevant knowledge.

Disadvantage and marginalization can be problematic to recognize and address, particularly where school systems are not adapted to such needs, and where there are deep-rooted social, cultural and economic factors. These can take different forms and kinds of solutions. Where there is purposeful liaison with a particular community; e.g., the Roma communities in different parts of Europe, and recognition of legitimate identities, there can be clear gains in ways in which students meet their legitimate aspirations (Nistor *et al.*, 2014). Where schools can seem threatening and

*R. Levinson, University College London Institute of Education, London, UK

oppressive to some groups, arrangements can be made to carry out inquiries in other arenas outside of them (Ellsworth, 1989).

While recognising diversity implies openness (willingness to listen to others, respect what others have to say, and change one's mind if convinced by better reasons), it does not imply agreement. What drives dialogue is difference and controversy (Hess, 2009).

Compassionate justice, minimisation of suffering, is a driving factor within RRI. *Science for society*, means that fruits of technology are distributed fairly, and that we have a mutual obligation to fellow inhabitants of the planet and a sensitivity to power relations which often distort those obligations. Renewal of life can be expressed as recognising “the interdependence of human life within a living planet as a source of both constraint and indeterminacy of human plans” (Simon, 1992, p. 27). Taking sustainability seriously entails respect for responsibilities we have towards each other.

Citizenship Education (CE)

CE can be seen as a continuum from knowing what is entailed by citizenship to having a more active concern for seeking justice. The term *critical CE* can also be interpreted in different ways from one which focuses on critical thinking to an emphasis on praxis; i.e., reflection and action as well as constructive dissent (Levinson, 2010). A useful framework, in the light of activities discussed, to represent the dimensions of critical CE is adapted from Johnson and Morris (2010) (see Table 2).

TABLE 2: DIMENSIONS OF CRITICAL CITIZENSHIP EDUCATION WHICH INCORPORATES PRINCIPLES OF COMPASSIONATE JUSTICE, SECURING DIVERSITY AND RENEWAL OF LIFE (ADAPTED FROM JOHNSON AND MORRIS, 2010)

<Insert Table 2 here>

*R. Levinson, University College London Institute of Education, London, UK

The horizontal row: politics, social, self and praxis, represent the component elements of critical citizenship education while the vertical column represents the necessary attributes. Each cell describes how each attribute exemplifies each element with the brackets indicating how they might be manifested in the context of SSIBL within the classroom.

Deliberative dialogue is at the heart of the democratic process which incorporates the substantive meaning of dialogue as communication between participants but also the appropriate dispositions, such as listening, equality, respect and openness (Rice & Burbules, 1992) which presuppose constructive dialogue. In addition, this dialogue incorporates criticality, an ability to identify and respond to logical inconsistencies and unsupported assertions. Reasonable people hold their views open to criticism and are prepared to justify them or revise their views in the light of more compelling arguments. Deliberation goes beyond dialogue in that in the democratic context it involves free and equal citizens giving reasons to settle socially urgent questions (Simonneaux, 2014) on which they have divergent views (Enslin & White, 2003). In the context of schools, deliberative dialogue has much in common with Neil Mercer and Karen Littleton's (2007) construct of group exploratory talk where students share relevant information about a problem, listen actively, and where everyone contributes, helping to build up on ideas to reach agreement. This drive towards consensus is one of the historic features of democratic deliberation (Habermas, 1984). While these features need to be aspired to in the democratic classroom, this is not always the case because dialogue is always mediated by power, this can be through positions of status (teacher and student), differential access to knowledge (scientist and layperson) and inequalities in social and cultural capital (Gamarnikow & Green, 2000). Effectively, this means that what might be seen as a normative view by most students in a classroom might be seen very differently by one or two others who might feel disinclined to make their views known, again a case of inclusivity. For example, a teacher and the class might start off from the proposition that global warming is an important issue to address while a small few may feel differently, perhaps because they feel far more pressing concerns or that people close to them have very different views from the rest of the group.

Democratic deliberation needs to be fostered in the classroom and cannot be assumed. It also presupposes an environment where students trust each other as well as the teacher and where questioning habits have been encouraged. The SSIBL process itself can encourage such an environment but encouraging constructive dialogue in the classroom might need to be built up and nurtured over a period of time. How conditions for constructing democratic deliberation in the classroom are facilitated depends on the teaching and learning context. In an environment where teachers and students are used to arguing and discussing in an open and respectful manner, attaining SSIBL will be relatively unproblematic. However, in more authoritarian learning environments many adjustments will need to be made, hence the structural and political positioning of schools within a broader social domain. A more gradual approach is necessary where students could be taught procedures for group talk then go on to develop their own procedures.

Critical citizenship education also incorporates a knowledge of political and moral concepts such as rights and equality. These are not necessarily mutually supportive concepts: ensuring equality might mean restricting rights. While rights — with responsibility — and equality are desirable they can only be discussed in relation to their limitations. For example, if parents have the right to pay to choose the sex of their baby this will have implications for equality, ethical values and natural justice. Interdisciplinary arrangements in school may be needed to foster these components, for example, planning for SSIBL with science, history and citizenship teachers collaborating.

Socio-scientific Issues (SSI)

Socio-scientific issues comprise conflicting opinions about a course, or courses, of action which have a scientific content and impact upon communities or society. They are controversial when good reasons can be given for conflicting opinions and/or courses of action (Dearden, 1981). There can be different levels of controversy. At one level a controversy might be solved upon the production of relevant evidence, e.g. differences about the best material for lagging an animal house can be tested based on experiments to measure temperature difference. On the other hand, there

may be core differences of values which are less easily settled such as whether it is right or wrong to abort a foetus under certain conditions. (Levinson, 2006). Where there is controversy, particularly as they impinge on core values, strong *emotions* may be aroused. It is important that such matters are dealt with sensitively, that participants are listened to with critical respect, and encouraged to be open and honest (Hodson, 2014). This is not an easy situation to achieve and will depend on the culture and the nature of collaboration within the group. One of the skills underpinning teaching SSIs and also SSIBL is to help create an atmosphere of mutual respect in the classroom, attempting to understand what is in the mind of the ‘other’.

Learner competencies in SSIs include employing ‘scientific ideas and processes, understandings about science and social knowledge (e.g. ideas about economic and ethical influences) to issues and problems that affect their lives’ (Sadler, 2009, p.13). Goals for student participation in SSIs vary. Some see the main goal as being legitimate participants in social dialogues which are science related (Sadler, 2009) while others maintain that *socio-political action* is a more urgent outcome (Bencze & Alsop, 2014). Socio-political action implies asking questions about ‘how research priorities in science are determined’ (Hodson, 2014, p 68.), whose interests are considered in formulating policy, and how action can influence policy decisions. It also implies commitment to reflective change, while Wolff-Michael Roth and Angela Calabrese Barton (2004) propose that such action is necessarily collective (see Table 1). In SSIBL we encompass goals emphasizing participation and socio-political action, indeed the second presupposes the former. While RRI presupposes participative dialogue, inquiry into SSIs is *non-trivial*, i.e. it involves students as critical citizens who learn how to enact goals which reflect aspects of social justice. (By non-trivial we draw a distinction between activities which involve simulation, i.e. writing a letter to a political leader as an exercise where the letter will never be sent, as compared with actions which are enacted, and *realised*, through the process of social and political participation. However, an action might involve deciding not to change if, for example, such a change risks too much harm.)

SSIs, and hence SSIBL, present particular challenges for organising learning and assessment precisely because they are transdisciplinary and context dependent. Approaching an issue depends to a large extent on our personal history, our social situation, our intentions, needs and wants, and our knowledge and experience of the issue. Stein-Dankert Kolstø (2001) offers a framework for examining the science dimensions of SSIs which have potential for contributing towards an assessment framework. These are:

- i. Science-in-the-making and the role of consensus – how is scientific knowledge made and how do its claims come to be validated?
- ii. Science as one of several social domains that contribute towards decision-making. This is central to SSIBL because there are a number of issues which are ostensibly based on science but where science knowledge may not be the main factor in decision-making, see for example Chris Dawson (2000). In these formal school science might be redundant (Ryder, 2001) and expert knowledge might itself be contested (Layton *et al.*, 1993).
- iii. Distinguishing between descriptive and normative statements.
- iv. Demands for underpinning evidence. In some cases evidence may be unambiguous but in complex SSIs this is rarely the case. It also involves matters of trust about whose evidence is more convincing, and how that evidence was amassed.
- v. Scientific models as context-bound which raises questions as to how scientific models are applied to complex situations involving a range of social and political factors.
- vi. Values; the way in which values influence our thinking and responses to an SSI.
- vii. The relationship between scientific evidence, i.e. that which comes from experts and anecdotal evidence, which comes from a range of lay sources.
- viii. Suspension of belief, being sceptical about the relationship between evidence and the conclusions which can be drawn.
- ix. A critical attitude, learning to ask the questions which are able to scrutinise knowledge claims.

All these dimensions have relevance in SSIBLs and values and critical attitudes apply to transdisciplinary inquiries generally. While these dimensions are unlikely to feature simultaneously in SSIBL they are, nonetheless, helpful as pedagogical resources to support decision-making and argumentation.

Rosemary Hipkins et al. (2014) use the term ‘wicked problems’ which illustrate well the kinds of controversies that SSIBL aspires to. These are serious social challenges which span multiple domains (social, economic, moral, aesthetic, political) and link closely with other problems. There are no clear solutions and different groups of people believe they have answers which often contradict one another. ‘Wicked problems’ do not have finite or unambiguous answers but in dealing with them, other interesting questions emerge.

Inquiry Based Science Education (IBSE)

At the core of the SSIBL framework is inquiry-based learning. Inquiry in the U.S. was promulgated by the philosopher and educationalist, John Dewey (1916). Dewey saw its democratic potential as a means for citizens to participate through solving problems of mutual concern and developing habits of mind of curiosity and communality. IBSE has been influential in science education policy both through the National Research Council (2000) and the EU (Rocard *et al.*, 2007) who conceive of science practise as question-driven and open-ended. The fundamental features of inquiry based learning are consistent with the proposed SSIBL framework: purposeful research-driven learning through collaboration, critical examination of evidence and experience. The main distinguishing point of SSIBL is that it involves an authentic open-ended question or hypothesis formulated by students, teachers or other interested parties, and taking action. Since student interest, research, questioning and the collection and interpretation of evidence underpin inquiry they are components of the role of inquiry-based science learning in the SSIBL framework (Figure 5). However, there are no specific design stages to inquiry-based learning in SSIBL. Student interest is not always spontaneous, and in most cases, will involve teacher preparation and competence in nurturing student interest. Inquiry in the context of SSIBL has features which are quite distinct from those normally attributed to inquiry based learning in science education.

Scaffolding inquiry teaching and learning

Since our characterisation of inquiry is seeking knowledge through evidence to answer authentic questions, inquiries need to be based on student interests. Through the introduction of inquiry-based learning students should feel empowered to direct their own learning through collaboration within a community of learners. Students might find it difficult to generate researchable questions if inquiry-based learning is new to them. One strategy for reaching the stage of genuinely open inquiry is first through a structured approach, then through guidance with teacher support and then open inquiry, similar to a STEPSWISE apprenticeship approach (See Table 2), although teacher judgment here is crucial. Too great a dependence on structured inquiry could impede moves to open inquiry.

Scaffolding is the process whereby learners are given appropriate support to help them learn something which they could not achieve on their own. It is a central pivot to social constructivist learning because it presupposes support can be given at a stage when the student is ready for it and can then be phased out when the learner has acquired the required competence. The precise nature of the support depends on a range of factors, what needs to be learned, the knowledge and skills the learner already has, the experience they have of the context of learning, the complexity of the concepts and skills to be learned, the knowledge and skills of the facilitator.

Time is also a factor. Short term inquiries would have outcomes which could be completed in one or two lessons or sessions and carried out mainly within school. Long term SSIBLs would go beyond this time and often include external agencies. Examples of short term SSIBLs are;

- Situating a feeder for nesting birds;
- Designing a poster to reduce school energy consumption;
- Organising a system for building the school compost heap;
- Bringing in plants for a community garden.
- Producing a leaflet to show how to estimate maximum salt intakes.

Such short term projects can meet the framework for SSIBLs. As well as different time spans for SSIBL these can also be structured from inquiries which are mainly closed and directed mainly by the teacher to those which are more open. Structured inquiries will help make explicit to students the knowledge and procedures necessary to carry out an inquiry.

Authenticity

Questions generated through inquiry are deemed to be 'authentic'. However, 'authentic' risks being a catch-all term with multiple, sometimes contradictory, meanings. In the context of SSIBL authentic questions can be the kinds of questions that scientists raise although the discourse between scientists in a research project, often influenced by political, cultural and economic factors, will be very different from that of school science (Quigley, 2014). In NRC terms authentic practice is linked to student ownership of the learning process although that raises difficulties when students encounter learning experiences which are genuinely challenging and need guidance. The Galileo Educational Network (Galileo.org) conceives of authenticity as focusing on problems and issues relevant to students in the 'real world'.

For Anne Hume and Richard Coll (2010), authentic problems are those which are ill-defined, have no obvious solution, where data has not been collected and there are no established goals and methods, a condition which is unlikely to be attained in the vast majority of school-based inquiries in science. Rather than attempt an overarching definition for authentic practice in SSIBL it would be more helpful to identify its main components:

- i. Proceeds from questions which interest and engage students and through which they express a wish, and choose, to find answers;
- ii. A mutually agreed purpose of all participants (i.e. a social authenticity)
- iii. What is relevant and has value and meaning (i.e. personal authenticity)
- iv. Where scientific ideas are a resource and can be activated to help find a solution to the problem.

There are therefore implications. A mutually agreed purpose may go beyond the bounds of the school walls for participants, particularly where in finding the answers to questions, students might work with scientists, or other people with expertise. SSIBL might involve interaction either in informal education contexts and/or working with agencies outside the school. An example of this is a collaboration between scientists and students in a school in east London with a high proportion of students of Bangladeshi origin. The collaboration stems from an inquiry into the pattern of diabetes in the family histories of the Bangladeshi community in east London. Students at the school, using their background socio-cultural knowledge, work with university scientists, health practitioners and the local political authority in devising a questionnaire. In the university laboratories under the guidance of scientists, students learn sophisticated analytical techniques on DNA found in affected families.

To ascertain what is relevant and has meaning is made real through participation and democratic dialogue where participants become agents of change transforming a reality which can be improved. Finally, activating scientific ideas as a resource might not be straightforward. It might involve distributed knowledge where different parties can contribute through their own experiences and expertise (Roth & Lee, 2002). But it also encompasses questions of scientific uncertainty. Consider, for example, a project which involves testing the pH of potentially polluted waters in a stream. Most school students when they encounter pH measurements use a pH meter or pH papers in ideal conditions. However, measuring the pH of a stream means taking flow, turbidity and temperature into account, thinking about sampling techniques, and being able to assess error. When students begin to work in non-ideal situations the limitations and uncertainties of scientific practise become clearer.

Developing the Framework for SSIBL

Based on the account above in elaborating the principal features of SSIBL, Figure 5 models the possibilities for SSIBL incorporating the components from Figure 1 and listed in the previous sections.

Figure 5: SSIBL framework <Here>

There is no set format for the order in which the pillars of an inquiry might be arranged. Inquiries might start with a question, followed by planning, perhaps reframing the question after planning, data collection and interpretation, and subsequently communication and taking action based on findings. These stages are likely to be iterated at various points, however. Alternatively students might be exploring data, and research questions might emerge from the data. Data might involve carrying out surveys or using ethnographic methods.

Figure 5 is *a framework to be aspired to*. It is recognized that teachers will go through different routes in building up to SSIBL.

A ubiquitous question, particularly from younger students, is ‘what are we doing this for?’ For some activities, such as early-stage reading, the answer is long-term, complex and a straightforward answer might demean the purpose. But in the case of SSIBL it is quite a legitimate question, and the socio-scientific purpose needs to be clear if the process is to have meaning.

Actions are linked to authentic practices, the aim is to change affairs from being unsatisfactory to more desirable ones. For example, there is a difference between students discussing the most efficient ways to conserve fuel use, or answering a set question on this topic, and those who design and build the school animal house based on an inquiry into the best way to cut down electricity bills. This action component is, arguably, a distinctive feature of SSIBL, and models that of STEPWISE. Hence authentic action components are oriented in the students’ educational and social settings, and they play a role in transforming the materiality of students’ lives, in however small a way.

Ideas or questions or hypotheses for SSIBL should aspire towards the following attributes:

- i. Openness (i.e. no pre-set answer)
- ii. Authenticity
- iii. Comprise different and conflicting perspectives (i.e. controversy)
- iv. Links between personal and social relevance.
- v. Participatory (i.e. all students should be able to take part and co-operate in addressing the question)
- vi. It should be researchable (i.e. either primary or secondary data can be gathered and interpreted to answer the question)
- vii. Focus (i.e. it should be narrow enough so the relevant data is containable)
- viii. Feasibility (i.e. it should be possible within time and curriculum constraints to answer the question)
- ix. Epistemologically appropriate (i.e. it should draw on science knowledge which students have or can be taught, and/or support the building of relevant knowledge).

When studying a topic students can have a space in which to formulate their own questions. There are a variety of ways in which this can be opened up. Students could brainstorm where they suggest various ‘raw’ questions, there is a follow up time to choose questions which students prioritise, followed by group work in which they frame the questions with the properties above (Table 3).

Assessment

Assessment of students in SSIBL depends on the purpose of the assessment and the nature of the assessment – whether it is diagnostic, formative or summative.

Laurence Simonneaux (2014) identifies four didactic strategies, slightly adapted, that can also reflect assessment purposes. These are:

- A doctrinal strategy that aims at the acceptance of authoritative scientific concepts.
- A problematising strategy that focuses on students' reasoning through SSIBL.
- A critical strategy that aims to develop capabilities in scrutinizing claims, to be questioning of expertise and to appreciate the uncertain nature of science and its applications and that the development and production of technology carries risks.
- A pragmatic strategy to engage students and to promote student action.

The framework of SSIBL assessment is adapted from Table 2 and incorporates:

- Knowledge about an issue (both scientific and transdisciplinary)
- Skills in organizing and operationalising a socio-scientific based inquiry.
- Values that reflect issues of social justice and wellbeing.
- Dispositions that include recognition of inclusivity and democratic deliberation.

Table 4 is a grid that can be adapted depending on the context of SSIBL.

Figure 6 summarises assessment for progression through the four dimensions of knowledge, skills, values and dispositions..



Considerations in Relation to STEPWISE

In conclusion I want to emphasise three distinctive aspects of SSIBL.

1. Inquiry in SSIBL is not formulaic and might be quite different from inductive-based inquiry. It involves asking authentic questions where the solutions are diverse, politically-constituted and complex, and involves drawing on domains of knowledge beyond science. In that sense they have much in common with the Socially Acute Questions approach (Simonneaux, 2014).
2. Inquiries should stem from students' own interests and motivations. This might not always be possible and is an aspiration. An important aspect of skilful pedagogy in SSIBL is helping to stimulate questions which promote a genuine sense of inquiry in students.
3. Actions of SSIBL are *non-trivial*. They involve informed actions which make a difference to individual and social wellbeing.
4. Actions are collaborative and enmeshed within a web of interested human and non-human relationships. Their realisation is therefore uncertain and the processes of achievement of aspirations based on social justice are risky. That leads to the production of knowledge-in-action, reflecting and acting on the inter-relationships between knowing the world and the vagaries of action, rather like disturbing a network of human and non-human actants (Hoeg & Bencze, 2014).

The last point does raise the question of what is meant by action. Just as the social applications of technoscience carry accompanying hazards, risk and uncertainties (Ravetz, 2005) so the intentions of actions are carried out in a sea of uncertainties. An example is an incident based on the AR activity described above where a discussion among students resulted in homophobic sentiments being expressed, which were then challenged. For any action in the social world to succeed it must rely on collaboration and an element of reliance on others (Arendt, 1998). Participation and trust are crucial in a diverse and plural society where values might vary enormously. So, the achievement of a particular outcome is only a partial measure of success; the importance of negotiation and participation based on shared knowledge, and the understanding of what is possible in sometimes unpromising circumstances, is a core part of the learning process.

References

- Arendt, H. (1998). *The human condition* (2nd ed.). Chicago, IL: University of Chicago Press.
- Baird, J., Isaacs, T., Johnson, S., Stobart, G., Yu, G., Sprague, T., & Daugherty, R. (2011). *Policy effects of PISA*. Oxford, UK: Oxford Centre for Educational Assessment.
- Ball, S.J. (2013). *The education debate* (2nd ed.). Bristol, UK: The Policy Press.
- Baudrillard, J. (1994). *Simulacra and simulation*. Ann Arbor, MI: University of Michigan Press.
- Bencze, L., & Carter, L. (2011). Globalizing students acting for the common good. *Journal of Research in Science Teaching*, 48(6), 648-669.
- Bencze, L., & Alsop, S. (Eds.) (2014). *Activist science & technology education*. Dordrecht: Springer.
- Crick, B. (1998). *Education for citizenship and the teaching of democracy in schools*. London: Qualifications and Curriculum Authority.
- Dawson, C. (2000). Selling snake oil: Must science educators continue to promise what they can't deliver? *Melbourne Studies in Education*, 41(2), 121-132.
- Dewey, J. (1916). *Democracy and education*. New York: Macmillan.

- Ellsworth, E. (1989). Why doesn't this feel empowering?: Working through the myths of critical pedagogy. *Harvard Educational Review*, 59(3), 297-325.
- Enslin, P., & White, P. (2003). Democratic citizenship. In N. Blake, P. Smeyers, R. Smith & P. Standish (Eds.), *The Blackwell guide to the philosophy of education* (pp. 110-125). Oxford, UK: Blackwell Publishing.
- Gamarnikow, E., & Green, A. (2000). Citizenship, education and social capital. In D. Lawton, J. Cairns & R. Gardner (Eds.), *Education for citizenship* (pp. 93-113). London and New York: Continuum.
- Giddens, A. (2008). *The Third Way: The renewal of social democracy*. Cambridge, UK: Polity Press.
- Habermas, J. (1984). *The theory of communicative action*. Boston: Beacon Press.
- Hargreaves, A., & Shirley, D. (2009). The persistence of presentism. *Teachers College Record*, 111(11), 2505-2534.
- Hess, D. (2009). *Controversy in the classroom*. New York: Routledge.
- Hipkins, R., Bolstad, R., Boyd, S., & McDowall, S. (2014). *Key competencies for the future*. Wellington, NZ: New Zealand Council for Educational Research.
- Hodson, D. (2014). Becoming part of the solution: Learning about activism, learning through activism, learning from activism. In L. Bencze & S. Alsop (Eds.), *Activist science and technology education* (pp. 67-98). Dordrecht: Springer.
- Hoeg, D., & Bencze, L. (2014). Counter cultural hegemony: Student teachers' experiences implementing STSE activities. In L. Bencze & S. Alsop (Eds.), *Activist science and technology education* (pp. 575-596). Dordrecht: Springer.
- Humbel, L., Jolliet, F., & Varcher, P. (2012). 3 key competencies in ESD for learners and teachers: Make a deconstruction, operate a reconstruction and ask critical questions. A case study in college classrooms about some SAQ (Socially acute questions) concerning 'le fait religieux' (unpublished paper).
- Hume, A., & Coll, C. (2010). Authentic student inquiry: The mismatch between the intended curriculum and the student-experienced curriculum. *Research in Science & Technological Education*, 28(1), 43-62.
- Jasanoff, S. (2003). Technologies of humility: Citizen participation in governing science. *Minerva*, 41, 223-244.
- Johnson, L., & Morris, P. (2010). Towards a framework for critical citizenship education. *The Curriculum Journal*, 21(1), 77-96.
- Kolstø, S. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, 85(3), 291-310.
- Layton, D., Jenkins, E., Macgill, S., & Davey, A. (1993). *Inarticulate science?* Driffield: Studies in Education Ltd.
- Levinson, R., & Turner, S. (2001). *Valuable lessons*. London: The Wellcome Trust.
- Levinson, R. (2006). Towards a theoretical framework for teaching controversial socio-scientific issues. *International Journal of Science Education*, 28(10), 1201-1224.
- Levinson, R. (2010). Science education and democratic participation: an uneasy congruence? *Studies in Science Education*, 46(1), 69-119.
- Mand, C., Duncan, R.E., Gillam, L., Collins, V., & Delatycki, M.V. (2009). Genetic selection for deafness: The views of hearing children of deaf adults. *Journal of Medical Ethics*, 35(12), 722-728.
- Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking: A sociocultural approach*. Abingdon: Routledge.
- National Research Council. (2000). *Inquiry and the National Science Education Standards: A guide for teaching and learning*. Washington DC: The National Research Council.

- Nistor, N., Stanciu, D., Vanea, C., Sasu, V.M., & Dragota, M. (2014). Situated learning in young Romanian Roma successful learning biographies. *European Education Research Journal*, 13(3), 311-324.
- Novas, C. (2006). The political economy of hope: patients' organisations, science and biovalue. *Biosocieties*, 1(3), 289-305.
- Osler, A., & Starkey, H. (2001). Citizenship education and national identities in France and England: inclusive or exclusive? *Oxford Review of Education*, 27(2), 287-305.
- Owen, R., MacNaghten, P., & Stilgoe, J. (2009). Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy*, 39, 751-760.
- Pierce, C. (2015). Learning about a fish from an ANT: Actor network theory and science education in the postgenomic era. *Cultural Studies in Science Education*, 10(1), 83-107.
- Quigley, C. (2014). Expanding our view of authentic learning: Bridging in and out-of-school experiences. *Cultural Studies of Science Education*, 9(1), 115-122.
- Ravetz, J. (2005). *The no-nonsense guide to science*. Oxford: New Internationalist/Verso.
- Reis, G. (2015). Social dimensions of scientific knowledge: The '\$5 bottle of hope'. *School Science Review*, 96(356), 27-30.
- Rice, S., & Burbules, N. (1992). Communicative virtues and educational relations. *Philosophy of Education*, 1992, 34-44.
- Rocard, M. (2007). *Science education now: a renewed pedagogy for the future of Europe*. Brussels: European Commission.
- Roth, W.-M., & Lee, S. (2002). Scientific literacy as collective praxis. *Public Understanding of Science*, 11, 33-56.
- Roth, W.-M., & Calabrese Barton, A. (2004). *Rethinking scientific literacy*. New York & London: RoutledgeFalmer.
- Ryder, J. (2001). Identifying science understanding for functional scientific literacy. *Studies in Science Education*, 36, 1-44.
- Sadler, T. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education*, 45(1), 1-42.
- Selwyn, N., Gorard, S., & Williams, S. (2001). Digital divide or digital opportunity?: The role of technology in overcoming social exclusion in U.S. education. *Educational Policy*, 15(2), 258-277.
- Shiva, V. (2000). *Stolen harvest*. London: Zed Books.
- Simon, R. (1992). *Teaching against the grain: Texts for a pedagogy of possibility*. New York: Bergin & Garvey.
- Simonneaux, L. (2014). Questions socialement vives and socioscientific issues: New trends of research to meet the training needs of post-modern society. In C. Bruguiere, A. Tiberghien & P. Clement (Eds.), *9th ESERA conference selected contributions. Topics and trends in current science education*. Dordrecht: Springer.
- Thomasian, J. (2011). *Building a science, technology, engineering and math education agenda: An update of state actions*. Washington, DC: National Governors Association.
- Vasagar, J. (2012, June 12). Michael Gove's curriculum attacked by expert who advised him. *The Guardian*. Retrieved from <https://www.theguardian.com/education/2012/jun/12/michael-gove-curriculum-attacked-adviser>
- Von Schomberg, R. (2013). A vision of responsible innovation. In R. Owen, M. Heintz & J. Bessant (Eds.), *Responsible innovation*. London: John Wiley.
- Wilkinson, R., & Pickett, K. (2010). *The spirit level: Why equality is better for everyone*. London: Penguin books.

