Of clouds and cables: what do students need when they learn with technology?

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ABSTRACT
Discussions of technology and education often promise revolution, and freedom from the constraints of campuses and classrooms. There is less discussion of why such infrastructures were needed in the first place, or of the challenges facing learners when these are no longer available. In order to explore such critical alternatives, we can begin to ask different kinds of question. What is the cloud made of? What do learners work with, when they study? Where are they, and what places do they move between? From a sociomaterial perspective, such questions draw attention to the ways in which academic work is encoded, transmitted and stored; how the cloud, far from being nebulous, relies on undersea cables and server farms; and how learners try and coordinate all this as they take bus journeys, sit in class or meet with friends in the bar. These points will be illustrated with examples from a longitudinal study of University students' uses of technology, in which they recorded and described how, where and when they studied. This analysis has implications for the design of e-learning, raising questions about whose responsibility it is to build the infrastructure that students need to learn, and introducing a note of caution to discussions about the transformational potential of technology.

CCS Concepts
• Social and professional topics → User characteristics →Cultural characteristics

• Human-centered computing → Ubiquitous and mobile computing → Ubiquitous and mobile computing theory, concepts and paradigms

• Networks → Network services → Cloud computing

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Keywords
Learning technology; infrastructure; networks; sociomaterial theory; education in the cloud

1. INTRODUCTION
It is often claimed that technology has the promise of a radically different educational future – for example, there is hope that technology might help cope with the estimated 125 million additional Higher Education places needed globally by 2020 [1]. As of yet, however, this promise has proved remarkably elusive.

There are many reasons why this hoped-for future has failed to arrive. One is that we have failed to understand the problems that learners face. In this paper, one aspect of this problem will be explored and its consequences for learners will be illustrated.

2. The problem of space in Higher Education

2.1 Framing the problem
Researchers of technology and education have long been fascinated by the 'martini' model of online learning, which refers to the Martini Rosso advertising slogan: "any time, any place, anywhere" [2]. This interest can be seen, for example in the assertion that MOOCs will overthrow the 'brick and mortar' campus [3], or the claim that Google is threatening "the monopoly (or at least hegemony)" of lecturers and University libraries [4, p16].

Similar claims have been made for the use of cloud computing in education. It has been suggested that this allows students to extend learning beyond the institution, create personalized learning environments without the need for technical skills, and to allow applications to be used at home or on campus without the need to pay for additional licenses [5, p135]. Sultan suggests that, even though cloud computing involves vast data centers and server farms providing on-demand resources and services over a network, "the term "cloud" was probably inspired by IT text books' illustrations which depicted remote environments (e.g., the Internet) as cloud images in order to conceal the complexity that lies behind them" [6, p110].

González-Martínez et al [5, p133] adds that the paradigm involves offering "a pool of virtual resources (hardware, development platforms or services) available over the network." This imagery, and the focus on virtualization, suggests something intangible and ephemeral, and separates the materiality of cloud-based computing from discussions of educational practice.

2.2 The problem with the problem

Discussions of space in Higher Education tend to frame it as a *problem*, with technology then positioned as a *solution.* Such arguments then focus on liberating teaching and learning from the 'constraints' of time and place [7].

However, education already takes place outside of 'closed', formal institutions, and analyses show that this move can bring problems as well as opportunities [7, p157]. As education reaches into workplaces, homes and other sites of study, it extends the reach of discipline, normalization and examination. It also encounters the constraints these new settings bring. The workplace may not simply liberate learners from instutions, but can instead become just "another container, into which students can be fed, and therefore engulfed or swallowed up" [7, p162].

So much attention has been focused on overcoming the problems of space and the constraints of the campus, "there is a distinct lack of consideration for how learning might take place once these obstacles are overcome" [8, p824]. This issue has been explained in terms of the difference between positive and negative forms of liberty. The primary concern in these problems is "emancipation from hierarchies of control and the bypassing of systems which condition admittance to knowledge" [8, p823]. Universities are positioned as a bottleneck and associated with exclusion and closure. There is no consideration of the positive freedoms – what people can choose to do – that are enabled by the existence of the systems and infrastructure.

2.3 The opportunities of infrastructure

The field of Science and Technology Studies has shown that knowledge work is shaped by both social influences and material concerns [9]. Ethnographies of laboratory work, for example, show that scientific claims rely on tissue samples, chemicals, machines, print-outs, desks full of academic papers and rejected draft manuscripts as well as practices, accounts and other social activities [10].

Although these material components are important, they are also easily overlooked: material infrastructures are typically taken for granted, in spite of shaping knowledge practices in profound ways [11]. Certainly, their absence would make any attempt to re-create those knowledge practices difficult, if not impossible.

Because the spatial and temporal coordination of knowledge is important, what Latour calls 'centres of calculation' have been created to bring together the specialised instruments and inscription devices that are needed [12]. Such centres have always been important for education: Bengtsen argues [13], such spatial and material considerations are vital to schooling, and have shaped their history. He describes, for examples, Comenius' interests in "the character of the school as a physical place with specific material objects and spaces […] full of luring and enchanting things" [13, p179] that might inspire people to learn.

So, then, instead of eliminating the 'constraints' of education, an alternative perspective would be to ask what people are able to do when resources, experts, tools and technologies are brought together within spaces designed to support learning.

2.4 Reframing spaces as 'resourceful constraints'

Consideration of resources and infrastructure draws attention back to material concerns that might otherwise be overlooked. Metaphors such as 'the cloud' hide the infrastructure that supports learning, suggesting instead that learners are somehow 'free floating' and that learning is an entirely abstract or cognitive experience. Because of this, it would be premature to reject or ignore the value classrooms, community sites, technologies and human bodies in our accounts of learning [14]. Instead, we need to consider how assemblages of human and non-human actors are brought together to enable learning to take place successfully – what Law refers to as heterogeneous engineering [15].

Cornford & Pollock [16] have explored the relationship between virtual and physical university sites. They recognize the limitations physical spaces impose, but describe the campus as a 'resourceful constraint', one that has persisted precisely because "the campus – or more generally, the co-location of learners, teachers, labs, class-rooms, lecture theatres, libraries and so on" – [16, p181] remains so useful to so many academics and students. As a consequence, they challenge advocates of flexible provision and distance education to consider what is lost as well as what is gained when such material resources are given up in the move to 'open' education, or to cloud-based systems.

2.5 Reaching beyond the campus

The analyses outlined above drawn on Actor-Network Theory (ANT), or post-ANT theories such as sociomateriality. Jones & Healing [17] argue that the networked analyses entailed by this kind of perspective reveal how what seem to be "simple choices between online and face-to-face, or between distance and local, become increasingly complex as educational designs blend a variety of components in a variable geometry" [17, p320]. Studying the practices of students on a conventionally 'closed' course, they demonstrated that the institutionally-provided infrastructure accounted for only part of the learning that took place. Learning more frequently took place in learners' homes or residences, as well as across social networking sites, through SMS text messaging or using Voice Over Internet technologies, as well as by meeting face-to-face in a range of formal and social settings.

This analysis reveals why campuses are so important: they are a site where many learners study. Such spaces become important because of the prevalence of their use. As a contrast, other spaces are important because they are used extensively by individuals – spaces such as their own homes – or because they provide exceptional opportunities – such as fieldwork sites. What all of these sites share is that students can use them to create the heterogeneous networks they need in order to study.

This perspective – one that follows learners, rather than focusing on static locations – shows how the infrastructure needed for learning is distributed, being taken up and reworked in different sites of study. Learning can be thought of as tied to specific sites; however, it can also be associated with resources that bring continuity and coherence to studying [18]. For example, it may be the use of the same device – a laptop, say – that ties different episodes of study together. It may not be a universal component, but may nevertheless be used widely enough to become an important component of their study practices.

There are similarities between this kind of analysis and discussions of 'Personal Learning Environments'. These environments, however, are often described purely in terms of the services and technologies used, without any reference to the platforms, spaces, people, books or other material elements that might be involved (e.g. [19]). For example, González-Martínez et al [5, p136] talk exclusively about the use of Application Programming Interfaces (APIs) to create "completely customized learning environments suited to the needs and preferences of

students". From a networked perspective, such APIs may be important points of connection between parts of a network, and may facilitate its construction, but on their own they cannot constitute the complete 'environment' for any given learner.

2.6 Tracing the network

There is no right way to draw a boundary around the kind of networks described above, because connections can always be traced to new or additional components [20]. Methodologically, a decision will always need to be taken about where to make a 'cut' and stop following links or connections.

However, the kinds of cuts suggested by the discussions in sections 2.1 and 2.4 are consistently limited. A metaphor such as 'the cloud' could suggest that learners remain 'free floating', and that the material infrastructure that they use to enable them to study can be ignored.

Starosielski has drawn attention to the way, for example, that the kinds of services delivered from 'the cloud' actually depend on very prosaic and self-evidently material resources, such as "undersea cables, the infrastructures that currently support over 95 percent of transoceanic internet traffic and transmit much global visual culture" [21, p39]. This material infrastructure is typically hidden (e.g. by burying it) or ignored (e.g. becoming invisible through repeated use), except sometimes at points of transition (e.g. where an undersea cable comes ashore) or when it breaks. A particular concern is the vulnerability of such infrastructure to malicious damage, for example through terrorist attacks – particularly since these cables follow routes marked out by a combination of convenience and politics. For example, in the late 19th Century, undersea communications cables were integrally connected with the extension and connection of the British Empire; the legacy of these politics still influences the negotiations needed to maintain and develop the system.

Further, Starosielski has explored where these cables lead, looking for example at the ways in which "the need for cooling is shaping the geography of global Internet distribution, relocating some of its nodes to the colder climates of Oregon and Scandinavia" [22, p2]. She argues that mapping 'media heat', including the intensity of energy use, can help reveal how media enfold and give rise to environmental relations.

In addition to looking outwards along cables and points of connection, it is also important to look at the details of students' practices. Hayles has challenged the idea of 'virtuality', a metaphor that is central to discussions of the cloud. She points out, for example, that information patterns are always instantiated in material objects. For example [23, p75]:

"The digital computer is not, strictly speaking, entirely digital. At the most basic level of the computer are electronic polarities, which are related to the bit stream through the analogue correspondence of morphological resemblance. Once the bit stream is formed, it operates as digital code. Analogue resemblance typically reappears at the top level of the screenic image, for example, in the desktop icon of a trash barrel. Thus digital computers have an Oreo cookie–like structure with an analogue bottom, a frothy digital middle, and an analogue top."

This has consequences for understanding how students work, and particularly for the way in which they work with and produce texts (a term that, in this context, includes multimodal as well as textual resources). Texts, Hayles argues, must always be embodied to exist in the world [23, p60], even if that embodiment consists only of storage in polarities on media in a server farm somewhere in a desert. The relationship between that stored form and subsequent display on a monitor draws in a complex material network, whether or not the student is aware of this – and whether or not the complex network is hidden behind the metaphor of 'the cloud'.

It also has implications for pedagogy, since these networks 'leak' past conventional boundaries around teaching. Lecturing is often held up as the quintessential exemplar of Higher Education. Gourlay's analysis [24] of contemporary lecturing shows how this involves a range of online and print resources, creating digital slides that are presented live but also made available online via Virtual Learning Environments (VLEs) and being 'lecture captured' for broadcast or access after the event. At the same time, students may combine listening with downloading resources from the VLE, texting friends who didn't make the session, checking social networking sites, tweeting, making their own recording of the lecture, and so on. The students' experiences of the lecture, as well as the lecturer's approach to teaching, are shaped by the material devices they have to hand, the availability of cables for power and data, and the connections these provide to places and resources well beyond the hall or campus.

2.7 Implications for design

If learners create environments for study using spaces, people and things, and technology helps them to draw in increasing remote and distributed resources as part of this, design faces two problems. Firstly, the environments being designed are unstable, even ephemeral, and are being constantly patched up or reinvented across times and places. As Hayles argues:

"With the centralization of information facilitating and accelerating the uses that can be made of differential variations in locales and labor markets, the material disposition of physical plants and human bodies becomes much more malleable than under the Fordist regime. Increasingly, material constraints come to seem like options rather than givens, negotiable indefinitely as long as the information connections are extensive and fast enough." [25, p150]

The second problem is each individual who might previously have been thought of as a 'user' instead becomes a designer. The designers of technical systems can make infrastructure available, but cannot control the uses that are made of it. Feenberg [26, p113] describes these limits on design in terms of the separation of strategy and tactics:

"Power expresses itself in plans which inevitably require implementation by those situated in the tactical exteriority. But no plan is perfect; all implementation involves unplanned actions in what I call the "margin of maneuver" of those charged with carrying it out. In all technically mediated organizations margin of maneuver is at work, modifying work pace, misappropriating resources, improvising solutions to problems and so on. Technical tactics belong to strategies as implementation belongs to planning."

This idea of the margin of maneuver describes the space of improvised design undertaken by learners on a day to day basis as they make and remake their sites of study.

3. Research Methodology

If cloud-based education consists of improvised design, in which learners access, read and create resources that they may have to hand, or may be connected to by cables laid under land and see, how can it be studied?

An approach was developed in a project that explored students' study practices within Higher Education, drawing on sociomaterial perspectives [27]. Institutional ethical clearance was secured, and the British Educational Research Association ethical guidelines were followed. All participants gave their informed consent for their involvement. The names used here are pseudonyms chosen by the participants.

In order to understand how students created these heterogeneous networks, an ethnographic perspective was adopted. After background work involving a survey and focus group, studies were conducted that focused on the day-to-day academic practices of students and academic staff, including the materiality of their work.

Participants were all drawn from one UK institution with a predominantly postgraduate student body. Institutionally, students are predominantly mature, and most are female. A dozen students volunteered to undertake longitudinal, multimodal journaling to document how they studied. As described in section 2.5, students' studying is distributed, and they are mobile; conventional forms of ethnographic observation were not possible. Instead, participants used iPod touch devices to take photographs and videos of the sites and resources they used when studying, over a period of 9-12 months.

Students were interviewed 3-4 times. The first interview explored their educational biographies and their previous experiences of using technologies in their studies; as part of this they drew sketch maps of their academic work. In each subsequent interview, the participants presented the images, videos or resources (such as folders, post-it notes, annotated print-outs and so on) that they brought with them, and discussed how these represented the way that they studied. Four members of staff also undertook this process, although they were involved for a shorter period (6 months) and only interviewed three times each.

The data were analysed thematically, coding the interview transcripts and then relating the images and other forms of data to the excerpts where they were discussed.

In the following section, vignettes drawn from the dataset are presented in which the complex networks that individuals assembled can be traced.

4. Findings

4.1 Juan's library

Juan, a Masters' student, talked about working in the library in order to draft an essay. He produced a series of images to illustrate this, organized into a complex flowchart. An excerpt from this is presented in

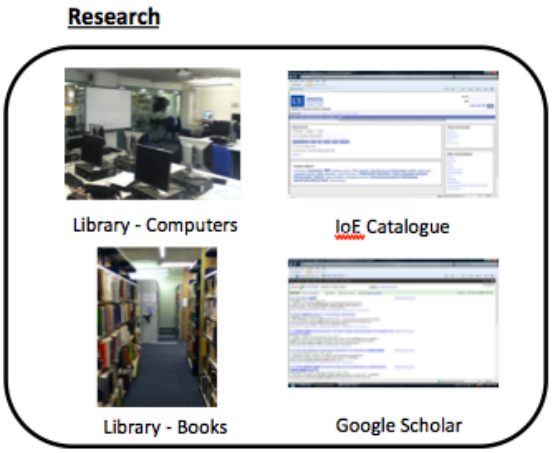

Figure 1, showing how he researched the topic of his essay.

These images show a mixture of material resources (books on stacks, desktop computers in a cluster room) and screen-based services (Google Scholar and the institution's own library database). He also described the ways in which he had moved between this space, where he worked on his own, and the student bar, where he discussed ideas with peers.

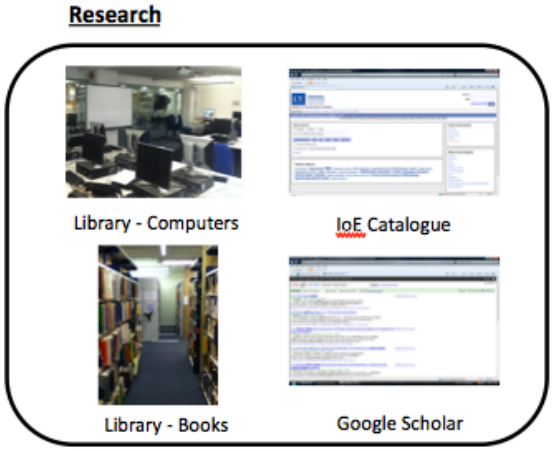

Figure 1: Juan's library

An important part of this process was how he read. He said he had found some resources by walking the shelves, locating a book and seeing what other texts were located nearby; at other times, he had searched for a concept or idea using one of the search engines. When he did this, he read through titles online, and sometimes also skim-read the text itself.

Through this process, he developed a shortlist of texts that he wanted to re-read in more detail. He wanted to read these in printed form, however; he found this supported a more reflective style of reading, and it also allowed him to annotate and mark up the text. However, he did not like printing articles off in this library, as the printers only supported single-sided printing; he objected to the cost and the environmental impact of this. Instead, he downloaded the texts as PDFs onto a memory stick and walked to the library of an adjacent college. Here, he logged into a desktop computer using his girlfriend's ID and password, and used their networked printers to run off a double-sided copy of the articles he wanted.

From a networked perspective, then, "Juan's library" was not a constrained site defined by the walls of his home institution. Instead, it consisted of a subset of the books and shelves relevant to his topic; a desk, which gave him space to manage his laptop and other resources, and a place to plug in his devices, connecting him to the power network; a desktop computer, connecting him via cables to the servers where the institution kept its databases, and then on via the UK's Joint Academic Network to the databases of publishers, stored somewhere unknown in a server farm; a USB stick on which PDFs were encoded; the short walk between two buildings; another institution's library; his girlfriend, and specifically, her identity on the other college's network; their desktop, network and printer; to the supplies of toner and paper for which he had to pay; and ultimately, to the pens and highlighters with which he marked up the printed article as he read it.

4.2 Yuki's iPad

Yuki, another Masters' student, brought along an image that she titled, "the bathroom is a good place to read" (Figure 2).

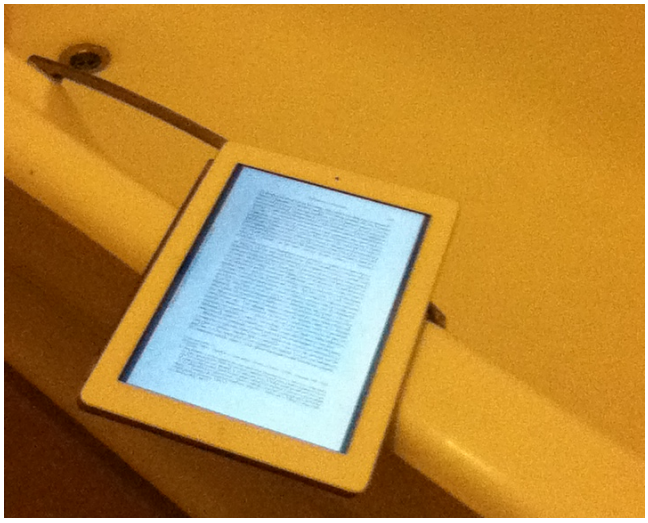

Figure 2: Yuki's iPad

Yuki explained that the iPad enabled her to study in the bath by allowing her to access a wide array of the resources she needed for studying. She described how she had accessed the course Virtual Learning Environment over wifi from the iPad. She had also searched for digital readings, using Google Scholar. With both these services, she downloaded PDFs that she wanted to read. Earlier, on campus, she had also used the iPad to record lectures, which she intended to refer to.

She also used the iPad to store copies of books that were not available from the institution, and which she could not find online. In order to do this, she bought second-hand copies of the books she wanted; microwaved them, to melt the glue that held the pages together; put the pages through a high-speed scanner to digitize them; re-bound the books; then loaded the digital files onto her iPad.

When she had assembled the resources she needed on the iPad, she ran a bath, put the iPad into a clear, zip-locked plastic bag, and took it into the bath to study.

Yuki's iPad acted as a constant point of reference for her studies. From a networked perspective, this device enabled her to connect from her bath through wifi to the course's Virtual Learning Environment and to other online resources; through its storage, she connected to lectures that were long-since over, and through a scanner and microwave to books she wanted to read. She was able to improvise an effective but unconventional learning environment using this one device to provide continuity to her studies, one that would not have been anticipated by the course designers.

4.3 Gertrude's office

A principle of work that draws on Actor-Network Theory, such as the networked perspectives used here, is that it should be able to explain failure as well as success [9]. She drew a map of the places where she undertook academic work (

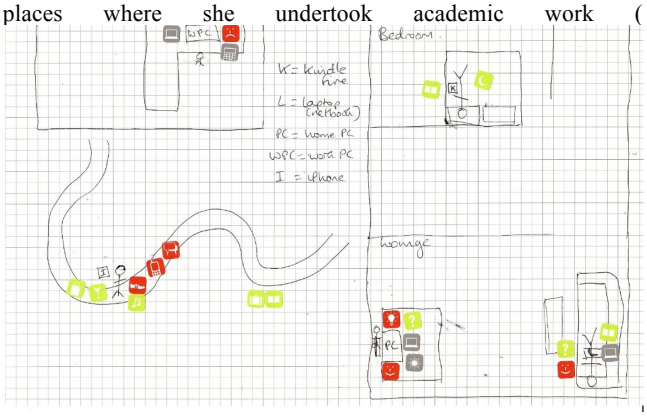

Figure 3), and described two spaces where she worked on course design: at her dining table at home, and in her office at work.

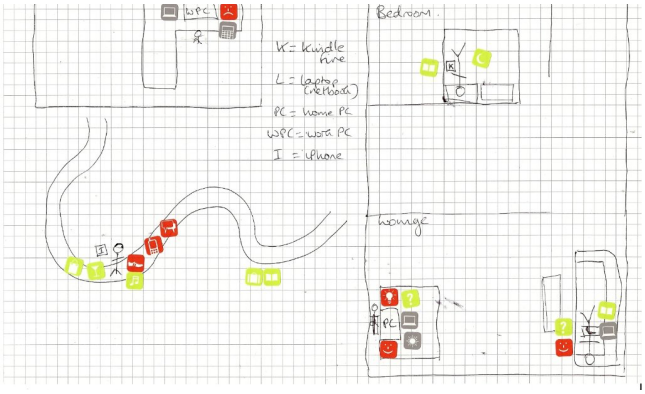

Figure 3: Gertrude's map

On the map, Gertrude used 'smiley' stickers to indicate how she felt about the different spaces. At home in the lounge, there is a 'smiley' face. Here, she had a computer setup that she had created, and over which she had complete control. This was connected to the Internet over fast wifi and a commercial provider's service. She used this to access the institution's Virtual Learning Environment, first authoring and then teaching an online course.

By contrast, her office has a 'sad' sticker. Here, she had a desktop computer, with access to the Internet via the national Joint Academic Network service. The same cloud-based services were available to her, but she was unable to use several of them due to the way in which the institutional computer was configured. She described how she had gone to the office to teach, but had found that she could not download the client software she needed to run synchronous conferencing sessions with students on her course. Even though this was officially an institutionally approved service, she did not have the administrative rights needed to install it.

Superficially, the cloud-based services available to Gertrude were successful; they were reliable and effective in achieving her educational ends. Focusing purely on APIs, services or infrastructure would not explain why this was insufficient for her to create a 'personal learning environment' in her office. Instead, the contrast between her home and office environments was determined primarily by how easy it was for her to negotiate the technical options that she had available. In the office, her 'margin of maneuver' was constrained by institutional IT policies to the point where she was unable to act; instead she opted out of that network and chose to use an entirely parallel one, over which she had more control.

5. Conclusion

The idea that technology will transform education is an over-simplification. It can support learners trying to study off-campus, whether or not they are officially classified as distance learners, e-learners and so on. However, in moving away from the campus, learners lose access to tried and tested configurations of resources that have been designed to help them study. When this is lost, new ways must be found to reconnect them to the people, things and spaces they need to study their discipline.

These new approaches are complicated, requiring learners to make their own sites of study from the people and resources they have to hand, as well as those that they can connect to, wirelessly or through cables. 'The cloud' may be useful as a simplifying metaphor to describe the services available to them, but designing cloud-based services or even architectures provides no guarantee that learners will benefit. The design of technology cannot guarantee learners will behave in desirable ways, any more than the ways in which learners choose to study will guarantee that well-designed technologies will be on hand to support them.

Nevertheless, there is an opportunity for technology design to inform students' study practices, and *vice versa*. Understanding what learners actually do, and why they do it, can suggest new design solutions. For example, in the vignettes above, simple changes to institutional printer settings or permissions on desktop computers made academic work easier. Similarly, Yuki's vignette shows how individuals can adapt their practices – and in some cases, extend them in surprising ways – in order to incorporate a new resource, such as an iPad. This two-way exchange between designed artifacts and individuals' practices requires learners to act as designers, taking more of an interest in the physical and digital resources available to them or that they can create; but it also requires designers to act as learners, finding out what users actually do, not just under ideal conditions, but day-to-day, and in a range of settings.

The examples presented here are, of course, purely illustrative; they suggest new approaches to study, but no claims are made about the prevalence of the specific practices described here. Such claims would be pointless: the important lesson from these studies is that they are particular and specific, and always will be. The challenge for designers is, then, not to design a better technology, but instead to create technologies that they can be taken up by users in many different ways, and in a range of possible settings.

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