Technologies of Participation: A Case Study of CSCL@Work in Mammography

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Abstract

We have been working with clinicians (mentors and trainees) to develop a computer-supported training environment for mammography. In this chapter, we draw on our experiences of this project to develop two important themes for CSCL at work. First, we explore how the training environment constitutes a 'technology of participation' that extends the range of practice-based experience available to trainees in order to further their professional development. Second, we illustrate how collaborative learning practices are instrumental in relevancing content and experiences to 'real world' practice and performance. Finally, we consider how to introduce new collaborative affordances that support for relevancing work in this transformed context.

Keywords breast screening, computer-supported training, communities of practice

Introduction

We report experiences from an ongoing project to develop a computer-supported training environment to facilitate the acquisition of the skills required to interpret breast X-rays (mammograms) in the UK Breast Screening Program. The aim of the project is to explore ways that computer-support can add value to existing workplace-based training in the development of professional expertise. The Breast Screening Program's move from film to digital imaging makes an investigation of screening training particularly timely. For example, exploiting the greater mobility of digital images and associated training materials may enhance opportunities for interaction and collaboration between trainees and their mentors, enable new modes of training and allow trainees access to rarer cases than they might ordinarily encounter.

Many of the chapters in this book explore learning in situations where the learning outcome is unclear and where the goal is to solve emergent problems or acquire competencies in novel social contexts. In these cases, the CSCL at work paradigm is concerned with the creation of new knowledge via collaborative learning practices mediated by Information and Communication Technologies (ICTs). Our chapter differs in that the learning outcome is well understood. The learner aims to acquire competencies that others already possess by participating in mature and highly professionalised work practices. What is less well understood is the impact of ICTs on participation. Our case study develops the notion of 'technologies of participation', a deepening of our understanding of how existing collaborative practices underpin the acquisition of professional expertise and an analysis of the interaction between technologies of participation and collaborative practice.

Our project brings together research groups at University College London, Edinburgh and Manchester Universities, and radiologists working at two UK NHS breast screening centres (Hartswood et al., 2009). To develop the training environment we followed a user-centred, participative design approach that built on our previous ethnographic studies of breast

screening (Hartswood et al., 2002). The training environment consists of two distinct tools, each of which addresses different aspects of mammographic image interpretation. The first tool enables senior radiologists (mentors) to select cases to meet the specific training requirements of trainees. The tool then replicates the conditions of everyday mammography reading practice and provides automated feedback in response to trainees' attempts at interpretation (Hartswood et al., 2011). The second tool, provisionally named 'Lesion Zoo', gives trainees access to a large number of abnormalities and rarer cases that they are unlikely to encounter in everyday reading work (Taylor et al., 2010).

This chapter documents early trials of a working prototype to explore how users (mentors and trainees) appropriated the environment's emerging affordances to support learning. In particular, we detail the emerging collaborative practices of mentors and trainees engaged in 'mentoring sessions', i.e. sessions where decisions made by the trainee using the training environment are retrospectively reviewed. The 'learning experiences' that arise from these encounters are shown to be collaborative achievements realised as a part of the participants' shared interactional practices. This focus enables us to identify various ways of providing the environment with affordances that enhance collaborative dimensions of its use and thus help address the question posed by Fischer in this volume: "How can we co-evolve a new understanding of learning, working, and collaborating, new media and new technologies, and new learning organizations?" (Fischer, RQ5)

As the chapter progresses we develop two themes. The first is how our training environment constitutes a 'technology of participation', providing a means for trainees to access materials and practice skills appropriate to their professional development. The second concerns how collaborative learning practices are instrumental in 'relevancing' content and experiences to 'real world' practice and performance. In particular, we examine:

- the divergent affordances of different 'technologies of participation', and how these shape the sorts and styles of collaboration that are possible;
- how the 'hard' affordances of formalised instruction (e.g. marks, structure, audit) interplay and are reconciled with 'softer' affordances of less formalised collaborative learning (acquiring confidence, maintaining autonomy, professional development);
- how computer-supported learning provides the opportunity for re-envisioning the mammography workplace and, in particular, its boundaries as a 'community of practice'; and

We conclude with reflections on lessons learnt for CSCL at work.

Breast Cancer Screening in the UK

Breast cancer is the most common cancer in women in the UK and the second leading cause of cancer death among women. A screening programme has been in operation in the UK for more than 20 years. The initial screening test is by mammography, where one or more X-ray films (mammograms) are taken of each breast. The usual types of mammogram taken are mediolateral oblique (Oblique) and craniocaudal (CC). Each mammogram is examined for evidence of abnormality by at least one trained reader (typically a radiologist). There is a very large range of normal and abnormal appearances, which result from a range of different types of breast tissue and different pathological processes. Abnormalities can be very subtle and interpretation can be extremely difficult. Indicators of malignancy include:

- micro-calcification clusters are small deposits of calcium salts visible as bright specks;

- ill-defined lesions are areas of radiographically-dense tissue appearing as a bright patch that might indicate a developing tumour;
- stellate lesions are visible as a radiating structure with ill-defined borders. Architectural distortion may be visible when tissue around the site of a developing tumour contracts;
- asymmetry between left and right mammograms may be the only visible sign of some lesions.

The practice of breast screening calls for readers to exercise a combination of perceptual skills– to find what may be faint and small features in a complex visual field – and interpretative skills to classify them appropriately, i.e. as benign or suspicious. Two reader performance parameters are particularly important: specificity and sensitivity. A high specificity (high true positive rate) means that few healthy women will be recalled for further tests; a high sensitivity (low false negative rate) means that few cancers will be missed. Achieving high specificity and high sensitivity is difficult.

Relatively few existing teaching aids have attempted to provide a richly interactive educational resource that is grounded in an understanding of how radiology is actually taught and how trainees learn. Those that do (Azevedo & Lajoie, 1998; Sharples et al., 2000) have focused narrowly on the formal instructive content of didactic encounters and neglect how these are parts of broader process of learning that links acquiring professional competencies with an engagement in the cultural, professional and historical regimes in which those competencies are applied (Lave &Wenger, 1991). Our own studies of reading work (Hartswood et al., 2002) point to how reading mammograms is observably not an isolated cognitive act, but an active social process since it is lodged within and orientating to a specific community of practice to which its members are accountable, an accountability that can be likened to Goodwin's concept of professional vision (Goodwin, 1994; 2000a; 2000b).

A particular focus for the project has been to redress this omission by asking how one might design a training environment that draws upon understandings both of the perceptual skills demanded and of contextualised professional conduct (Hartswood et al., 2002). To understand the implications of this for training, we turn to the concepts of 'situated learning' and 'technologies of participation'.

Situated Learning

Lave and Wenger (1991) developed the concept of situated learning from the observation that, in a range of situations, apprentices apparently progress towards competency without a well-defined programme of formal instruction (i.e. lessons, examinations, etc). Two key claims underpin the idea of situated learning. The first is that learning is not dependant on teaching, but rather is a constituent part of our participating in the social world:

> "Indeed, this viewpoint makes a fundamental distinction between learning and intentional instruction. Such decoupling does not deny that learning can take place where there is teaching, but does not take intentional instruction as the cause or source of learning, and thus does not blunt the claim that what gets learned is problematic with respect to what is taught." (op. cit. p. 40-41)

Problematising the relation between "intentional instruction" and learning has significant implications for those designing instructional programmes, especially where these are designed as proxies or replacements for on the job training. If instruction is not seen as the cause of learning, then one has basic difficulties in setting about creating resources or practices with the aim of inculcating skill or expertise. A number of authors have attempted

to reconcile pedagogy with situated learning. One approach introduces the concept of 'stolen knowledge'– i.e. by providing a resource of sufficient richness the learner is able to appropriate what they need from the learning encounter (Brown & Duguid, 1996). Another describes how teaching math in a way that reflects mathematicians' representational and problem solving strategies allows students to learn by engaging (by proxy) with the community practices of mathematicians (Brown et al., 1996). In our study, we see both the pedagogical intent in the shaping of the training environment and instructional content *and* the various unplanned, informal and situated methods the learner and the mentor employ to realise the trainee's use of the environment as a 'learning experience'. One key aspect of the latter concerns how the trainee and the mentor, working collaboratively, relevance their experiences using the environment to 'real world' practice.

Lave and Wenger's second claim is that learning is not limited to technical know-how, but rather that learning in the greater part involves becoming conversant with the socio-cultural history and organisation of the workplace. Taken together, these two claims form the basis for what Lave and Wenger refer to as *legitimate peripheral participation* in *communities of practice*, where *legitimate peripheral participation* describes the conditions for situated learning to be effective, and *communities of practice* encompasses the shared socio-cultural traditions of practitioners. Becoming a member of a community of practice is not simply about acquiring the appropriate technical competencies, but about acquiring an identity as a practitioner.

Legitimate peripheral participation

The phrase 'legitimate peripheral participation' expresses the idea that the trajectory from apprentice or trainee to full participant involves the trainee's engagement in the work setting so that they have access to a series of loosely structured 'learning experiences'. Most obviously, legitimation points to trainees' right to engage with the setting.

> "Master tailors must sponsor apprentices before the latter can have legitimate access to participation in the community's productive activities. In short, the form in which such legitimate access is secured for apprentices depends upon the characteristics of the division of labor in the social milieu in which the community of practice is located." (Lave &Wenger, 1991, p. 92)

In professional settings such as medicine, learners have additional entitlements over and above legitimate access to the work setting. Access itself is on a footing commensurate with junior medics' status as learners, whereby they are not burdened with the 'full workload' expected of skilled staff. Other entitlements include access to learning experiences (as per the example above) and having time to engage in 'non-productive' activities, such as attending college, time to reflect, undertaking 'learning' tasks that involve some element of practice, or acquiring theoretical underpinnings. Aspects of legitimation in professional settings like medicine also have a significant formal component, such as attaining certain qualifications or membership of professional organisations.

Peripherality relates to the mode of the novice's engagement with the setting:

> "To begin with, newcomers' legitimate peripherality provides them with more than just an "observational" lookout post: It crucially involves *participation* as a way of learning – of both absorbing and being absorbed in – the "culture of "practice." … From a broadly peripheral perspective, apprentices gradually assemble a general idea of what constitutes the practice of the community. This uneven sketch of the enterprise … might include who is involved; what they do; what everyday life is like;

> how masters talk, walk, work, and generally conduct their lives; what people who are other learners are doing; and what learners need to learn to become full practitioners." (Lave &Wenger, 1991, p. 95)

Participation is peripheral in the sense that novices have limited responsibilities undertake non-critical tasks, rather than because they are at a distance from the action. On the contrary, their involvement enables them to observe 'old hands' at work, to gain familiarity with craft materials and practices, to access expertise, get a feel for the routines and rhythms of the work and, by moving between tasks, get an overview of how different component activities of the enterprise mesh together. This point is further developed by Fuller et al. (2005) and Fuller and Unwin (2003) who point out that modern enterprises are comprised of multiple, overlapping communities of practice and that acquiring competence in each, and understanding how they articulate together, is an important part of becoming a full participant.

The medical apprenticeship has many of the features described above. Progression initially involves academic training, which in later years is coupled with placements, followed by on-the-job training rotations and specialisation. As part of this trajectory we see increased competence coupled with increased status, responsibility and autonomy. Until the very final stages of specialisation, there is a rotation though different clinical areas, providing trainees with an overview of the medical enterprise as a whole, and an appreciation of each of its components and how they interrelate.

Novice medics are regulated in the degree to which they can independently undertake clinical tasks both to protect patients and the medics themselves from being burdened with responsibilities that they are incapable of discharging. It is necessary to ensure the integrity of practice so that decision-making and procedure in breast screening remain of a standard that will guarantee the safety of women using the service. Later in the chapter we will see how a trainee film reader's participation is carefully managed to ensure that their safe involvement.

Technologies of Participation

In an exploration of how computer-supported learning can be informed by the concept of situated learning, McLellan (1996) highlights the role that technology can play in enhancing access to craft materials and demonstrations of expertise:

> "Technology is another central consideration in the situated learning model because technology expands the power and flexibility of the resources that can be deployed to support the various components of situated learning. For example, reflection is enhanced by the use of the various techniques for reproducing or *"replaying"* the performances of both expert and novice for comparison." (McLellan, 1996, p. 12).

While technology can mobilise workplace learning resources and improve their "power and flexibility" (op. cit), situated learning is as much about enculturation as it is about acquisition of narrowly defined technical skills. So, although replaying the 'performance' of an expert might allow physical moves to be examined and practiced with much greater ease, this type of presentation may do less well at conveying the ethical considerations in making certain moves at certain times. In the domain of surgery, Kneebone et al. (2004) describe how it is increasingly unacceptable for junior surgeons to undertake procedures on real patients, and how improvements in the fidelity of simulators provide an alternative, but argue that simulation "must be used alongside clinical practice and closely linked with it" (op. cit.) for precisely these reasons.

Use of simulators (surgical, or our training environment) can be thought of as proxies for 'authentic' workplace experiences. Such proxies offer new affordances with the potential to

enhance learning in the ways that McLellan suggests, but, at the same time, they can displace direct access to workplace activity with the risk of impoverishing the overall learning experience, a danger that Kneebone et al. acknowledge and seeks to guard against. In Lave and Wenger's terms, use of proxy learning experiences can deny access to relevant 'arenas of activity', limiting the novice's ability to acquire their identity as a practitioner. The importance of this is highlighted by Fuller et al.'s identification of "restrictive" apprenticeships where the novice's experiences of the workplace are narrowly constrained to a particular task or location, resulting in poorer motivation and a lower likelihood of career progression. We argue that the CSCL at work concept helps us here by maintaining a focus on collaboration as an activity of key importance to learning, and on the workplace as a place for learning. We argue the design of computer-supported learning environments has to attend to building in affordances for collaborative practices that help relevance their use to broader workplace concerns.

This chapter develops the idea of 'technologies of participation' to capture the different ways in which technologies mediate access to all the various aspects of practice, including to craft materials, expertise and work settings or arenas. Put another way, we are interested in how technologies aimed at supporting learning impact on a novice's status or effectiveness as a legitimate peripheral participant. The literature outlined above provides us with some starting reference points, and as the chapter develops we explore in greater detail the interplay between participation in the sense of gaining access to craft materials and expertise, and participation in the sense of being able to engage informally and collaboratively with practitioners.

Technologies of Participation in Breast Cancer Screening

Much training in mammography is conducted at work: an experienced mentor guides a trainee's interpretation of actual screening cases. There is a formal requirement for trainee film readers to read at least 400 screening cases every month for a year. The trainee reads 'live' screening cases and makes a decision on each, but not one that influences the outcome – the cases are still read in the usual way by qualified readers. In this way, trainees can participate safely in a real setting where they have access to experienced practitioners, can see them at work and examine their opinions and contrast them with their own. Their participation gives them access to the breast screening clinic as an 'arena of practice' – they are in a position to observe others at work, to consult with 'old hands' and develop a deep familiarity with the work of breast screening in the round. Some of this interaction is mediated by the dedicated paperwork on which the trainee records their decision, and upon which, at a later time, a qualified film reader will give their view of the trainee's interpretation.

The trainee's 'screening slip' (Figure 1) can be taken as a very simple technology of participation in that it provides a means for the trainee to safely participate in reading actual screening cases ('live' paperwork and decision-making is largely undisturbed) in an authentic setting – using equipment, and the physical organisation of materials is used in 'actual' screening, and at the same time affording asynchronous access to radiological expertise.

Training screening slips get passed back to the trainee after the cases have been read by senior radiologists, with comments where the trainee's opinion differs from the final decision. Also marked is the final decision and how it was arrived at, i.e. whether there was a consensus between the two readers, or whether the case went to arbitration.

Sara, the SPR[1] trainee taking part in our study further improvised use of the training screening slip, writing on the patient's CHI number[2], so that she could retrieve cases after the slip had been returned to her, allowing her to review the films in light of the other readers' comments. She also started keeping a record of the returned slips to self-audit the cases she had read in order to gauge her own progress, as well as developing a strategy of recalling cases as a means of eliciting feedback (a practice she carried over to her use of the digital training environment)[3]:

Sara: *So I know it's specifically at the moment I'm overcalling almost intentionally*

Mark: *Yeah*

Sara: *whereas I think if I was actually in a exam situation and being forced to come down the fence I would probably gone for normal … [on the training screening slips] I'll say I've seen these little opacities, these are the reasons I think they don't need recalled. They've either been there before or*

Mark: *ah ha*

Sara: *they look benign or they erm or I think they are com- they're technical.*

Mark: *Yes, ok*

Sara: *So I qualify the decision that I make but I kind of know that – for every – you can basically guarantee that every single one that I've put a little slip on in this situation I'd be flagging it as recalls so I got some feedback on it.*

Mark: *Ok.*

Sara: *It's my way of making sure I get feedback because otherwise there's no way of learning.*

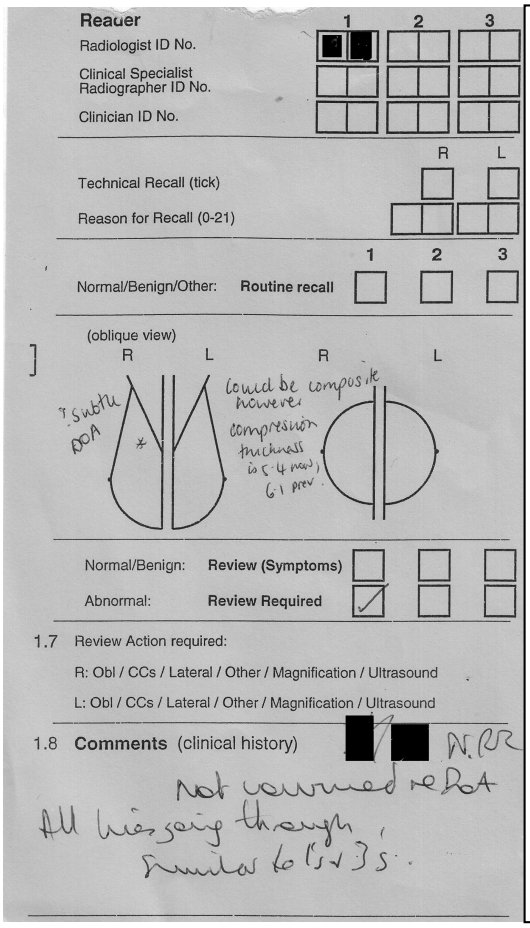
The trainee also indicated that the larger part of the feedback she received is via the use of the training screening slips, rather than talking directly to other readers. Although senior readers would be more than happy to give guidance on request, the trainee's reading sessions do not always overlap with those of other readers.

In this sketch of the training screening slip as a technology of participation various issues come to the fore. It evidently performs well at supporting decision-making in an authentic environment, and provides a means of accessing expertise in circumstances were co-location on a regular basis would be difficult to arrange. The trainee uses the system instrumentally to gain access to expertise by overcalling. Training slips make the trainee's performance partially visible to the senior readers, who will see the decision made by the trainee on cases they themselves are reading. They perform less well at providing a record of the trainee's performance; audit functions are improvised by the trainee but, by the same token, the trainee maintains ownership of their own audit.

[1] A specialist registrar (SPR) is a doctor undergoing final training before becoming a consultant in a specialist area of medicine.

[2] The CHI number is a unique numeric identifier, allocated to each patient on first registration with the healthcare system in Scotland.

[3] In the extract, Mark is the software developer.



The trainee has written: "? Subtle DOA. Could be composite, however compression thickness is 5.4 now, 6.1 prev?" and has ticked the 'Review required' box.

DOA stands for: Distortion of Architecture. The trainee wonders if what she is seeing is 'composite', i.e. due to a confluence of normal breast tissue, but notes the breast is compressed less in this image than in that taken at the earlier visit, which presumably has a bearing on whether composite structures might appear.

The 'reply' by the senior radiologist in the 'Comments' box starts out by indicating the decision of the two expert readers of the case, both identified by a number "xx/yy NRR". (Normal Routine Recall.) "Not convinced of DOA. All lines going through, similar to 3's". So the expert is not convinced that there might be a DOA, saying that "All lines going through" –lines radiating from a point indicate malignancy, but if radiating lines can be 'traced through' they are probably normal breast tissue. Also the expert makes reference to films - "3's"- from the third screening round where there are similar sorts of appearances.

Figure 1: Example of a training screening slip. The top of the form containing the patient identifier has been removed. The slip actually is a fragment of the form used for 'actual' reading by already qualified staff. There are three columns for the film reader's decision: 'routine recall', 'Normal (but) Review (symptoms)' and 'Abnormal Review Required'. This clinic operates a system of arbitration, whereby if there is a disagreement between the first and second reader, then a third reader has a casting vote (hence the three columns).

Later, we will contrast the affordances of the training screening slip and our training environment to demonstrate how they function in subtly different ways as technologies of participation. This analysis allows us to see areas where computerisation impacts upon the trainee's status as a legitimate peripheral participant and how collaborative affordances can be designed to compensate in cases where the impact is negative.

Development and Use of The Training Environment

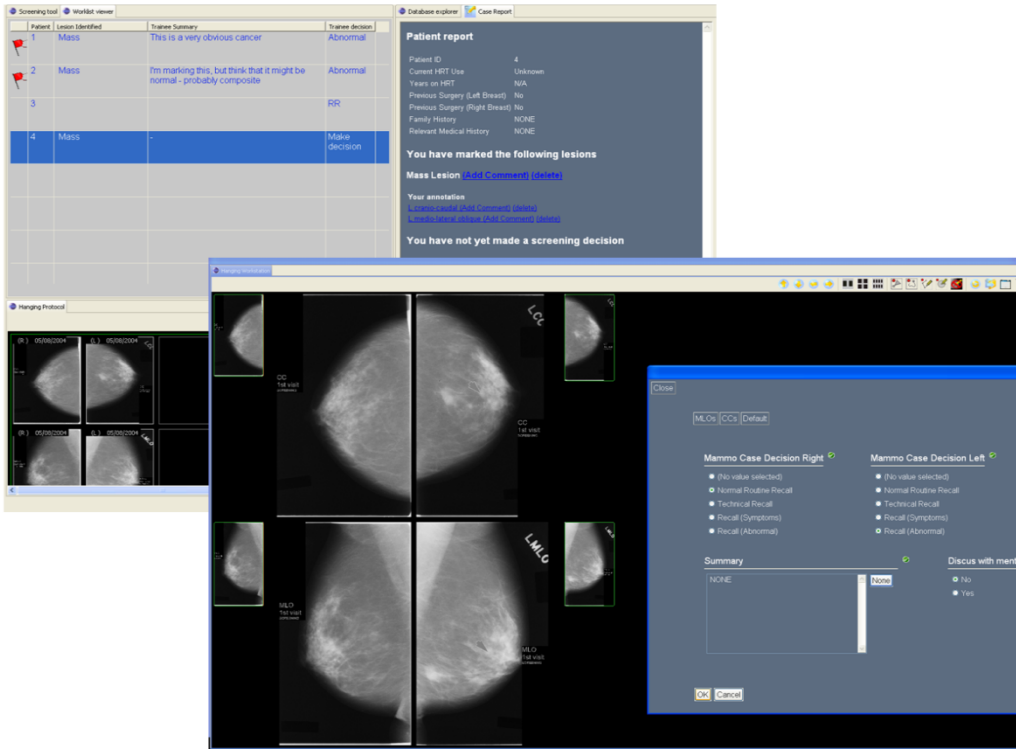
As Goggins and Jahnke note in their introduction to this volume, designing for collaborative learning is inherently socio-technical. Taking this seriously calls for following a user-participative, co-production or 'co-realisation' approach to the design and development of technical innovations (see Hartswood et al., 2008).

In this project, design and development work was initiated through with a series of meetings involving designers, potential users and domain experts where ideas and subsequently prototypes were iteratively worked up to a point where it was agreed that they were mature enough to be used by trainees. As we have described, training in mammography has an established repertoire of technologies and practices. Not surprisingly, therefore, the training screening slip – which itself is a replica of the normal reporting paperwork – was adopted as the initial template for the new training environment. Subsequently, the design of environment was iteratively evaluated and refined as we describe below. In its current

version, the environment allows trainees to mark a case in a number of ways (Figure 2). They can make one or more annotations, make a comment on a case, make a recall decision, or flag the case as one that they wish to discuss.

Two expert radiologists compiled a training set by selecting cases from an archive. In subsequent evaluation sessions two trainees used the training environment to work through the set's 91cases, 30 demonstrating an abnormality and 61 'time proven normals'. At intervals of 20 cases the environment gave the trainee the option of reviewing their decisions, and provided them with automated feedback based on prior expert annotation. While trainees can, in principle, use the training environment to learn independently, we were keen to explore how its use could be integrated with existing mentoring arrangements. Our trainees were given the opportunity to review cases they had read with their mentor. Both trainees found that reading roughly 20 cases using the environment in each session provided a reasonable tradeoff between comfort and making progress and both read all 91 cases during the course of 4 sessions using the environment. Our first trainee, a radiographer training to be a film reader[4], opted to have mentoring sessions for each batch of cases she completed, so she had four mentoring sessions in total. Our second trainee, an SPR opted to complete all four sessions with the environment before having a single mentoring session.

Development and evaluation were closely coupled throughout each of the above activities, which meant that trainees experienced different configurations of the environment as their sessions progressed. Some functionality accumulated during the course of the evaluation, for example, facilities to flag cases for discussion were available to the second trainee but not the first. On other occasions functionality was refined, for example, the way that the trainee's score was calculated and presented was revised a number of times over the course of the evaluation period.



[4] Radiographers' more usual responsibilities concern the production rather than the interpretation of screening images. It has become increasingly common and acceptable to train radiographers to read films as a means of addressing shortages of radiologists.

Figure 2: The training environment user interface. The interface enables browsing cases (rear-most panel), displaying the mammograms and making a decision (front-most panel).

Findings from Evaluation and Use

Each of the design, evaluation, training and mentoring sessions were video recorded and transcripts produced for subsequent analysis. Below, using extracts from these sessions, we provide some examples of the issues that arose. Some of these issues – which, broadly speaking, map to dimensions within clusters A (Human and Organisational Constraints) and B (Socio-Technical Design) in the conceptual framework outlined by Goggins and Jahnke in their introduction – help give shape to an analysis of the training environment as a technology of participation. Others, particularly those taken from the mentoring sessions, help us to envisage collaborative affordances that can enhance trainees' legitimate peripheral participation.

The first two fieldwork extracts concern aspects of how pedagogical intent is embedded in the training environment, and how it is recognised and managed by the trainee engaging with intentional instruction.

Selection of training materials

In this first fieldwork extract radiologists Jane, Mary and Ann are looking through the archive of abnormal cases and choosing cases appropriate for two training sets they are compiling. Jane and Mary are radiologists who deliver training, and Ann is a radiographer who helped compile the case archive from which our training cases are drawn.[5] Mary had left the room, but returns half-way through the extract.

Jane: *Yep. Erm. No, I mean we've got a fibroadenoma [Ann: hmmm] there. Oh. [Ann: That's interesting]. Oh, right, there's one up there.*
Mark: *Yeah there's two – there's two bits to it.*
Jane: *I thought it was two together, like a dumbbell shape that thing at the bottom but there's obviously one up there as well. Might – sbit confusing. It's like a lymph node.*
Ann: *Well that's something in its self that (u…?) (laughs)*
Jane: *I wonder if I made a new (… … …?)*
Mark: *Er. Two fibroadenomas. Learning points, one lesion only seen in one view.*
Jane: *CC.*
(Mary: returns)
Jane: *One of them is way up in the top there and we never saw it [Jane: yeah] and it isn't on the CC.*
Mary: *Yeah, no I don't think that's [Jane: That's too confusing, it's a bit] very good.*
Jane: *No, we won't have that one then. Right. Ok.*

Fibroadenomas are breast lesions that are not in themselves cancerous, but are potentially the site of cancer formation. They can be very subtle and are similar in appearance to 'architectural distortions', which do signify cancer. Fibroadenomas therefore represent an interesting exception to the basic pattern of breast cancer presentations and so are useful cases to include in a training package. In the extract above the radiologists are trying to make sense of the case with two lesions that Jane had initially thought were adjacent, but which turn out to be in quite separate parts of the breast. One of the fibroadenomas deviates from its archetypal appearance, and because of this, and its location, its presentation is confusingly similar to that of a lymph node. In the rejection of this case as 'too confusing' we can see the

[5] As before, Mark is the software developer.

'guiding pedagogical hand' at work filtering and sifting the case archive, tailoring it to meet the pedagogical intentions of its authors. In this example the set is shaped by rejecting a case that is too ambiguous or too complex, the fieldwork also included examples of rejecting or including cases on the basis of achieving a balanced mix of presentations, and rejecting cases that were considered to be too easy.

Formal instruction and actual practice

The 'guiding pedagogical hand' is also highly visible in the next fieldwork extract, where the trainee (Sara) comments upon the 'rapid reporting' component of the radiology exam:

Sara: *It's like exams we do for our radiology final exam we do a rapid reporting thing an it's basically A&E type films, hands, fingers, chests, abdomens. Bits of people. And, you've got to report in thirteen – how long – how many films do you get? Is it thirty films in half an hour? ... And you have to decide [Mark: that's one a minute] if it's abnormal or normal – yeah that's why it's called rapid reporting. Abnormal or normal and if it's abnormal you have to correctly identify the abnormality and people say oh no it's not – I think it does sharpen you up – it really does make you focus in on what's relevant.*

Like most exercises created with pedagogy or assessment in mind, the rapid reporting exam is easily distinguishable from real life film reading. Pedagogical intent is highly visible in the ways that such exercises variously identify and focus on component skills, distort frequency and mix of presentations, and disconnect the learner from resources normally available in practice (consulting with colleagues, taking time to reflect, ordering further tests, consulting with the patient and so on). What is evident in the extract is the need for the artificiality of the exercise to be explicitly managed by the trainee in order for its relevance to be clear to them[6]. The trainee orients to this when she says "[rapid reporting] *does sharpen you up... make you focus on what is relevant* [in a radiological image]." Such relevancies might not necessarily be found, as the trainee refers to other students with a different impression: "…*people say oh no it's not* – [a realist test of radiological skill]."

Collaboration between the trainee and mentor to find relevance in the trainees' experiences of using the environment is a recurring theme in the fieldwork, which brings us to the issue of *learning transfer*. Learning transfer concerns how learning experiences in one context are able to improve performance in another and has been an important phenomenon for learning theories to account for, particular those factors that might inhibit or enhance transfer (Subedi, 2004). In so far as transfer depends upon discovering the relevance *of*, and relevancies *in* an instructional encounter, our studies reveal it to be a practical accomplishment residing within the interactional practices of the participants. Although appreciating relevance and finding relevancies might not always depend on explicit collaboration, we find that relevancing work to be a highly visible and significant part mentoring sessions, and argue that support for collaborative relevancing work should have a prominent place within the CSCL at work concept. The remaining fieldwork examples explore in greater detail the different aspects of relevancing work undertaken by the mentor and the trainee.

[6] Pedagogy serves more than one purpose and trainees are aware of this. It is open for them to suspect that a given exercise may serve institutional or professional objectives rather than strictly educational ones.

Situating computer-supported training within the trainees' broader learning experience

Because trainees continued with their normal training at the same time as evaluating the training environment, they often accrued significant additional experience in between evaluation sessions. The discussion between the trainee and the mentor often referred to the trainee's progression over these periods as shown in the following extracts (Sara is the trainee and Jane the mentor):

Sara: *Show my [annotation] – I think it was this. And, yeah, it was this area here. [the trainee had annotated one area, but the lesion was in another] Again, I think now …*

Jane: *Having a second look you might feel*
Sara: *having – well just having done a lot more mammos.*
Jane: *(emphatically) Yes.*
Sara: *And have been to a lot more clinics.*
Jane: *So this one of the earlier ones that you did when you hadn't done an awful lot.*
…
Sara: *I would have pointed that – it's interesting actually now to go back through this again [Jane: Hmmm] with a bit more under your belt [Jane: HmmmMmm]*
…
Sara: *but I do actually think that it is useful now going back through the cases and seeing how with some time [Jane: How you've changed yeah]*

Here we can see the mentor and the trainee situating the performance captured by the training environment as belonging to specific moment in the trainee's learning career. This was one of a number of cases where an incorrect decision had been made, but where it was agreed that the trainee would be unlikely to make a similar mistake now, in light of her additional experience. Use of the environment provides a snapshot of the trainee's performance. It freezes a moment in time that can be revisited and re-examined from the perspective of greater maturity, an affordance the mentor exploits to build the trainee's confidence.

Note how the mentor and trainee reflect on use of the training environment in light of their other training and practice-based experiences in ways that are mutually illuminating. This seems to be part and parcel of working out what sort of learning experience the training environment provides and how it is relevant to and articulates with other learning and practice-based experiences. The training environment's ability to take snapshots of performance emerges as a key affordance in making progress perspicuous to both trainee and mentor.

Interpretative privilege

A further interesting aspect of the trainees' work of reviewing their prior decisions was that of 'interpretative privilege'. Trainees, on occasion, provided an interpretative context against which their scores or marks should be judged, rather than expecting that these should be taken at 'face value' as somehow directly representing the trainee's performance. For one trainee, Tina, this was often the performance of the system itself (because flaws were ironed out and features were added to the system as the training progressed).

Tina: *And not having that facility, I think, just having the ... the enlarge facility [the 'magnifying glass' enabling portions of the image to be seen in close-up, which did not function correctly during early training sessions with Tina] probably made me think that there was something – It does look like something on the CC.*

For a second trainee, Sara, it was that she often made recalls to elicit feedback, rather than because she 'really' wanted to recall the case.

Sara: *I would have gone …I knew I'd consciously did overcall on some things in this just to have them … just to have them flagged up.*

On the one hand, these can be seen to be entirely reasonable considerations. For example, although it is possible to flag a case or lesion without recalling it, it is entirely likely that the second trainee only gradually became aware of these possible modes of using the training environment as the sessions progressed. Similarly, for the first trainee, improvements were made to image presentation and quality over the course of her sessions. On the other hand, though, these sorts of comments signal how trainees sought to:

1. maintain control over how their score should properly interpreted and
2. create a 'distance' between recorded decisions and how far those decisions can be read as indicative of their performance.

We might see this as an important aspect of presenting evidence relating to trainee performance. Since the general idea is for trainees to progress, it is important for the trainee not to feel that they are 'saddled' with a particular score or mark, or to have a representation of decisions made seen to be definitive of their 'actual ability'. Any such point is always something that trainees need to be able to move on from as their skill and expertise matures. Trainees orienting to marks as transitional has similarities with fieldwork in the previous section where some sorts of erroneous decisions lose their relevance as the trainee grows in competence. This seems to be characteristic of a more general phenomenon whereby the trainee's accumulated learning experiences are woven together to create an overall 'narrative of progress', a topic we return to in the conclusions.

Scores or marks are summative accounts of performance that do not convey the circumstances in which they were acquired. Trainees seek to supply elided contextual particulars, highlighting the constraints on their performance at the time the marks were achieved in order to create a preferred frame for their interpretation. In a digital training environment, where decisions are persistent and marks perhaps available to others, then having control over their interpretation assumes greater significance.

Attending to errors

Where a trainee has made a mistake, the discussion with the mentor was found often to be diagnostic, and typically involved reconstructing a plausible account of how or why the trainee might have missed or misinterpreted something, and in doing so drawing their attention to broader classes of problems or pitfalls associated with reading.

Jane: *I think because she's – I wonder... Is it because you are thinking there is asymmetry and there's much more stuff going on here? So you've concentrated on that side? And maybe not looked...*

Often the mentor would also subtly point out or emphasise evidence that the trainee might have missed or weighed insufficiently, such as comparisons between views, or the possibility of teasing the lesion apart into its constituent (normal) components.

Jane: *Opacity. Not clear on oblique. So you saw something on the CC, so you mean that thing on the top there? … Hmmm. Just an asymmetric patch of breast tissue, isn't it? … I mean there's no distortion there's nothing particularly suspicious there I suppose I (...?) it does stand out if you're looking at it from here.*

It was typical also for the mentor to treat the trainee's decisions as generally credible and give the trainee room to 'argue' or 'hold out' for favored interpretations, as the mentor apparently endeavored to balance influencing the trainees' approach with allowing them flex their muscles as independent decision-makers.

Jane: *Well, yeah, I mean the reason you want to call it presumably is because it is sticking out of the back of the breast disk to some extent on the CC. Isn't it? [Sara: yeah] away, in a way. Yeah, no, that's a fair cop. (laughs) I can, I can understand you would (do that?) [Sara: I can talk you into that one] Yeah, yeah, no I'm not unhappy with that one.*

There are a number of interesting aspects to these encounters. The first concerns the, often, ambiguous character of breast lesions, which means that that film readers need to set a threshold for what counts as recallable or 'suspicious'. The mentor, in the comments above, is helping the trainee to establish a sense of where this threshold should lie. The second is that by engaging with the mentor in these discussions, the trainee is also engaging with the film readers' wider community practices, since this sort of mutual calibration and informal review is an important component of normal screening work. The discussions between the mentor and trainee can be seen as an extension of these practices, rather than as a detached episode concerned solely with 'knowledge transfer'. Use of the training environment supports participation by providing opportunities to have one's own decisions questioned, and to question the decisions of others, and importantly, to see how this questioning is done – how decisions should properly be accounted for, what sorts of etiquettes should be observed, when to hold out, when to give ground, and so on. Thirdly, because the mentor orients to the trainee as a practice member, for example, by treating their decisions as generally credible, the trainee can feel a degree of community acceptance that again helps marks progress towards full membership. This aspect can be seen in the way that the mentor takes care to build the trainee's confidence by careful choice of feedback, for example:

Jane: *No, you you've got two [i.e. found two lesions in the image] and the expert's only got one. For calcification lesion. So you've marked both the areas and the the so the expert hasn't seen the other one maybe... Yes, you're the smart one you see.*

The 'expert' referred to is the experienced film reader who originally annotated the abnormality in the film. As far as the training environment is concerned the trainee's second annotation is in error because it does not correspond to a region marked as abnormal by the expert. However, the mentor and trainee are both convinced that the second lesion marked by the trainee is also clinically significant. The mentor is able to emphasise the trainee's own developing expertise by pointing out how it compares favourably against that of an 'expert'.

In comparison with the nuanced accounts of the trainee's performance provided by the mentor, the training environment's own feedback often fared badly. Both trainees and mentors disliked our early attempts at automated marking, which consisted of simple metrics describing how often the trainee had agreed or disagreed with the 'expert' opinion. The main complaint was that the marks did not distinguish sufficiently between more and less clinically important mistakes and painted an overly negative picture of the trainee's ability, which the trainees found to be both unpleasant and discouraging. Although we refined the marking system so that it could distinguish between different classes of error, and can imagine refining it further, the degree of nuance available from mentoring sessions will always surpass capabilities of the automated system. An obvious example is that the automated system would never be able to work out the trainee had found an unmarked lesion as the mentor did in fieldwork extract above.

One issue evident in these extracts is the richness and contextualised character of the discussion between mentor and trainee, and how proxies are inevitably viewed as a consolation rather than a proper replacement. Even the training screening slip, which, while supporting better contextualised expert feedback than the training environment's automated provision, was still seen as 'second best' by Sara, who described it as "*having a conversation with a piece of paper.*" One important reason for this is that the rich learning opportunities afforded by conversing with a mentor arise not because a trainee straightforwardly has access to their knowledge, but because those discussions are actually constitutive of participating in a community of practice. This is perhaps also indicative of the general sorts of struggles apprentices have in accessing appropriate learning opportunities against the backdrop of competing demands on the 'masters' time. There is a legitimate balance to be struck between regulating learners' access to organisational resources and the provision of rich learning experiences, with important questions arising for CSCL at work as to the opportunities technology provides both for holding learners at arm's length, and for drawing them in.

The Training Environment as a Technology of Participation

In this section we compare and contrast use of the mammography training environment with current workplace-based training to show how each mediate access to craft materials, expertise and arenas of practice in very different ways. We are not presuming that our training environment could replace current training practices in the near future, or that this would necessarily be the most effective mode of use. Rather, the comparison aims to illuminate the differing affordances of the two approaches. That said, with breast screening centres in the UK poised to adopt digital mammography, it is not implausible to think that training provision will follow suit in time. Our comparison also presumes the computer-supported training environment is used as an independent learning resource – that is, used without explicit collaborative activities involving other learners, or mentors. Again, this is not a realistic assumption, but examining how delivery of a vanilla computer-based training programme stacks up against current training practice gives us purchase for identifying collaborative affordances that could be usefully built into the computerised tools. The dimensions of comparison are summarised in Table 1 below:

	Computer-supported Training	**Current Training**
Curation	Cases have to be selected for archiving and case materials have to be annotated	No pre-selection of cases – trainees see everything
Case Mix	Possibility of broadening access to cases from other centres	Case mix limited to what is available at the individual centre
Location	Potential to be inclusive of participants at a distance	Benefits of co-location – access to context
Expertise	Access to codified expertise	Access to actual experts

Realism	Relations to 'real practice' have to be explicitly attended to	Realism can be taken for granted
Tracking Progress	Records kept of trainees' decisions	Trainees' decisions ephemeral

Table 1: Comparison of computer-supported training with conventional, 'on-the-job' training.

Curation

In the conventional approach to training, craft materials (images, cases) are used naturalistically; but in the computer-supported training environment they have to be curated. That is cases have to be selected for inclusion in the training archive and case materials then need to be marked-up or annotated with meta-data – i.e. the 'ground truth' (diagnostic information where available) and information that affords subsequent case discovery, selection and re-use for training purposes. Importantly, much of this curation work must typically be repeated on a regular basis if the contents of the archive are to remain 'fit-for-purpose' over time.

Case mix

In current training, what trainees see is limited to cases available within the individual centre and does not exhaust all abnormal presentations. The mobility of digital data means that the digital training environment has the potential to provide access to cases sourced from different clinics, and so affords trainees' exposure to a broader range of abnormal presentations and training materials.

In this sense, the use of digital content may be seen as expanding the horizons of the trainee beyond the boundaries of the physical workplace. However, this may not be so straightforward as it might seem. Coopmans (2006) has challenged assumptions that mobility of data is afforded by digitisation alone, lending weight to claims that data is not so easily disentangled from – and hence used beyond – the context of its production (Carlson & Anderson, 2007). "An understanding of mobility […] draws attention to the craft like nature of that achievement: the artful connecting of time, space, material and immaterial elements into a 'mobility effect'." (Coopmans, 2006, p. 7) This view is corroborated by our own findings, which we report in more detail elsewhere (Hartswood et al., in review).

Location

Using the training environment a trainee would be able to access craft materials in a location independent way making participation more convenient. Moreover, because digital training cases are anonymised, and can be accessed without attending a live clinical setting, various ethical barriers to participation are removed. Therefore, a training environment, such as the one we have developed, has the potential to be more inclusive of a broader range of trainees. In contrast, co-location in conventional training provides a potentially richer learning experience because trainees have direct access to the work setting. The different permutations of locality and training approach are illustrated in Table2 below:

		Locality	
		Within clinic	Beyond clinic boundaries
Training approach	Conventional training	Good access to practice arenas Not see full spectrum of abnormalities	N/A
	Computer-supported training	Good access to practice arenas Access to a very broad spectrum of abnormalities	Limited access to practice arenas Access to a very broad spectrum of abnormalities

Table 2: Relation between locality and training approach.

Keeping computer-supported training within the clinic was the solution offered by Kneebone et al. for surgery simulators (op. cit.), and while this, in some ways, offers the best of both worlds, once established, remote training is likely to open up possibilities that are equally attractive, such as increasing the size of training cohorts. When training is delivered outside of the clinical setting then one needs to consider how access to practice arenas can be otherwise mediated.

Access to expertise

When used as a resource for independent learning the training environment provides access to codified expertise in the form of annotations delineating the location of lesions, an expert opinion of the case and a 'learning point' (both consisting of a short passages of free text). Much richer access is available in scheduled mentoring sessions, or informally as part of on-the-job training or asynchronously (in writing) via the training screening slip. It is notable from the fieldwork extracts that encounters with experts during mentoring sessions are unstructured, serendipitous, shift between different topics, and are highly contextualised. Experts not only provide 'expertise', but they also provide reassurance, help to build the trainee's confidence, and exposed trainees to community practices associated with interpreting mammographic images.

Realism

Trainees understand that they are engaging with an environment that has components that are more or less artificial or intentionally fashioned. In on-the-job training trainees get to see everything and anything; whereas, in a computer-supported training environment, trainees only see a pre-compiled set, put together with a particular purpose in mind. One question that arises is that of validity of the learning experience in relation to the 'real' task. While realism in conventional practice can more or less be taken for granted, realism in the training environment is something that always has to be attended to.

Tracking Progress

In current mammography training, training screening slips are thrown away. They are ephemeral. Outcomes of decisions in the training environments have a much more permanent character. In some of the fieldwork extracts we saw how the trainee managed this formal aspect of computer-supported training. On occasion, retrospective examination of errors provided trainees with a sense of how they had progressed between sessions using the training environment.

Discussion and Implications for CSCL@Work

We have seen above how the computer-supported training environment provides potentially significant benefits over current mammography training practice. However, it also raises a number of issues whose resolution we argue has broader relevance for CSCL at work.

Collaborative approaches to curation and case mix

Our experience in this project is that exploiting digital archives – selecting training cases, creating and renewing training content – are time-consuming tasks heavily constrained by the availability of expertise. The 'hand-crafted' approach to producing training materials that we have relied on to-date does not scale well. One alternative lies in the exploitation of 'social media' approaches, which have demonstrated that the mark-up of shared content can be distributed effectively between community members, a practice often referred to as 'social curation' (De Roure et al., 2010).

It would be important to explore, for example, how, by harvesting information generated as a byproduct of the use of the training archive, social curation could be used to add value incrementally to it and thereby shift the burden of preparing and curating training materials from a small number of experts to the wider community of mentors and trainees. The adoption of social curation techniques may also provide a solution to the challenges of making case materials usable for training beyond the context in which they have been produced.

Collaborative approaches to problems of location and access to expertise

Counter-intuitively, it is likely that trainees evaluating the training environment had more dependable access to expertise than they would in conventional training because of the mentoring sessions explicitly scheduled as part of the evaluation process. If deployed 'for real' it is likely that use of the environment would be more along the lines of an independent learning resource. The question arises then of what collaborative affordances might we use to ease access to expertise for users of the environment? This question is especially pertinent when training is remotely delivered to trainees, whose access to the clinical as an arena of practice will be greatly curtailed.

One approach would be to provide a digital version of the training screening slip with supporting experts' comments on trainee decisions for cases that the trainee flags as significant. In a digital version, the expert's comment could then be shared with *any* trainee who makes a similar decision. Thus, decisions and comments made by individual trainees and mentors could be exploited to benefit the wider learning community. Another approach would be to capture trainee reading or mentoring sessions on video and sharing these with other trainees to support 'vicarious learning' (Lee, 2006).

Collaborative approaches to problems of realism

One important aspect of the mentoring sessions was the work done to relevance the trainees' experiences of using the environment to their 'real world' practice. Many of the suggested collaborative affordances in this section support relevancing work of one form or another. It is worth pointing out, however, that it is hard for someone to engage in helping you find relevance in your use of the training materials unless they have some understanding of your accomplishments and requirements as a learner. This perhaps suggests the importance of supporting a relationship with a *single* mentor over the course of an apprenticeship. However, communities could play a significant role here too - communities of learners in particular

(which our research did not explicitly examine), who presumably also engage in collaborative relevancing work which could be amplified with appropriate computer-based tools.

Collaborative approaches to problems of tracking progress

An important aspect of providing collaborative affordances based on traces of the trainees' work concerns confidentiality and control. Trainees sought to maintain interpretative privilege over their performance as recorded by the environment, and a permanent record of trainee performance opens up the possibility of its appropriation for audit purposes in ways that might be controversial. For this reason, questions have to be explicitly addressed concerning who has access to the trainees' record on the training environment and under what circumstances.

There are a number of ways in which CSCL at work could provide 'biographical support' to assist trainees measure their progress over time. Most obviously, perhaps, are basic numerical scores detailing correct and incorrect decisions that can be compared if this or other sets are (re)taken at a future date. The sorts of occasions detailed above, however, provide additional opportunities for richer measures of progress. For example, identifying cases that remain hard for the trainee to interpret accurately provides a convenient way of indexing cases that require further review and reflection, which might then be re-inserted into future training rounds (comparison with other trainees' performance on those same cases would help to establish if they are intrinsically hard). As the trainee accrues still more experience they will presumably struggle with fewer of these cases, demonstrating how and where they are making progress, and where a trainee finds patterns of cases to be persistently tricky then the they can be directed to appropriate additional training exercises. If it is possible to establish the lessons represented by each case, then it would also be possible to present trainees with biographical account of what they have learned.

Concluding Remarks

In this chapter, we have attempted to address the question of how one might evolve CSCL at work to take advantage of the opportunities afforded by digital media to enhance mammography training.

Medical training is complex: it is multi-faceted and is layered over several years. The impact of any one element of training may be hard to gauge, yet somehow each contributes something to the trainee's growing technical and professional competence. If we consider the impact of a training environment such as this one from the perspective of the totality of the trainee's education then its overall impact is likely to be small. Also, we can see that it depends on aspects of that wider training for its own effectiveness, both in terms of the prior learning needed to be able to draw lessons from using the environment, and subsequent learning where those lessons become a resource in further assimilation.

In the fieldwork we could see how trainees and mentors relevanced their experiences by linking them into a broader narrative of the trainee's progress and professional development. Each trainee's narrative orders and makes sense of a diverse array of individual experiences, while at the same time having a common overall shape for all trainees, that is, one defined by specific passage points (passing a radiology exam), fixed durations (the length of a rotation), expected outcomes (a professionally capable individual) and so on. Much of this relevancing work and narrative construction turned out to have significant collaborative dimensions, visible, for example, in the way that the mentor demonstrated the trainee's progress by contrasting prior mistakes with current abilities. Identifying these allowed us to focus on ways of enhancing and extending collaborative relevancing work, including tools that more

effectively provide ‘biographical support’ for individuals to better gauge their own progress, and tools enabling aspects of individuals’ learning experiences to be shared with the wider learning community.

During the development and evaluation activities outlined above many possibilities emerged for enhancing computer-support for training in mammography that we have yet to fully explore. Among these include capturing a richer account of the context in which trainees made their decisions. This could involve using audio capture, capture of training environment use (e.g. mouse and keystroke events), capture by video of gestures, eye movement tracking and so on. While (as we saw above) there are cases for which there would be little interest in forensically reconstituting trainees’ reading, in others it might be highly productive and generative of opportunities for additional learning.

The development and evaluation of the mammography training environment has entailed exploring how a CSCL at work intervention can be made ‘at home’ in the context of a sophisticated and mature regime of training delivered in a complex, professional workplace setting. While evidently capable of generating rich opportunities for interaction between trainee and mentor, as highlighted in the sections above, use of the training environment also challenged mentors to develop new competencies and rethink the role and character of training delivery for different groups of trainees. While computer-supported training offers flexible and configurable modes of delivery, by the same token it raises questions as to which modes and configurations best suit which training circumstances. The ability to tailor content is a significant benefit of computer-supported training, but it also places additional demands on content creators, who have to acquire skills in set creation and invest considerable effort in curating training cases. Our experiences in this project show that a traditional, linear curation processes has significant bottlenecks that inhibit large-scale mobilisation of digital resources, and we have suggested social curation, where reliance is placed on harvesting community rather than individual expertise, as an alternative.

CSCL at work provides the opportunity for re-envisioning the breast screening workplace and, in particular, its boundaries as a community of practice. Conventional film-based training is necessarily rooted in a very clearly bounded locality: the breast screening centre that provides a ‘home’ for the trainee and is the source of both mentoring expertise and craft materials. The move to digital images, with their presumed mobility opens up the prospect of creating a much larger, federated resource of training cases accessible beyond the physical walls of the individual breast screening centre. Delivering mammography training outside breast screening centres may offer a number of advantages, not least of which would be increasing trainee numbers, but comes at the cost of limiting access to arenas of practice. Creating rich and portable representations of practice and expert engagement that can be shared and elaborated by other community members is perhaps one way of allowing community practices to be remotely accessible alongside training materials.

Finally, the presumed mobility of digital content is a key enabler of the possibilities outlined above. However, we suggest that making digital content re-usable beyond the immediate context in which it has been produced is as major challenge and makes it unclear to what extent mammography training might take advantage of the opportunities offered by CSCL at work. On that specific issue, social curation is one possible way forward, but much remains to be learned about how exploit this in practice. If social curation turns out to be a viable and effective technique for resolving problems of re-using digital content in mammography training, then we would expect it would have much wider significance for CSCL at work.

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