Contextualizing the Changing Face of Scaffolding Research: Are We Driving Pedagogical Theory Development or Avoiding it?

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Abstract This symposium will discuss how scaffolding research can inform the next generation of highly distributed and technology-rich learning environments. Contemporary technologies offer great potential to complete some of the activities that have been described as scaffolding. However, despite the wide body of research that has investigated the use of technology to scaffold learning, there is a lack of consensus about what the accumulated body of scaffolding research demonstrates, what the term scaffolding should mean and how we might operationalize the concept to meet the challenges posed by modern, diverse technology-rich learning environments and increasingly techno-savvy learners. There is limited research into scaffolding through wireless, mobile, tangible and ubiquitous technologies and insufficient theory development to take forward the principles at the heart of the scaffolding concept. This situation is compounded by lack of learning-centred definitions of context that can add a 'learning sensitive' dimension to the developments in 'context sensitive' computing.

Background

Research into scaffolding through technology has extended far beyond the adult and child interactions originally studied by Wood and his colleagues (Wood, Burner & Ross, 1976; Wood et al, 1992; Wood & Wood, 1999). For example, empirical studies have been undertaken with learners aged 5–11 years, studying a range of subjects including science and maths (Holmes, 2005; Butler & Lumpe, 2008). Work has also been completed with learners aged 11–18 years studying maths (Koedinger et al, 1997; Beal & Lee, 2008), science (Azevedo et al, 2005; Puntambeker & Styllianou, 2005) and history (Li & Lim, 2008). There have been numerous studies with older learners in college and in higher education, including trainee teachers (Oh & Jonassen, 2007); science students (Chen at al, 1992; Crippen & Earl, 2007; Ge & Land, 2004), and technology students (Tuckman, 2007). Researchers have not restricted themselves to scaffolding domain level concept learning and have also explored the potential for scaffolding to be used to support the development of affect and higher order thinking, such as metacognition (Aleven, et. al., 2004; Harris et al, 2009). Nor have they restricted their research to individuals: groups and the scaffolding of collaboration between learners has also been studied (see for example, Guzdial et al.,1996); Zurita & Nussbaum, 2004).

Research in CSCL has focused on facilitating collaboration by scripting and structuring collaborative interactions among students. Computer-supported scripts directly influence the collaborative dialogue, instead of training students prior to the actual collaboration (Schwarz, Asterhan, & Gil, 2009). For example, students are provided with carefully designed scripts to engage in processes such as argumentative knowledge construction (e.g., Weinberger, Stegmaan, Fischer, & Mandl, 2007; Weinberger, Stegmann, & Fischer, 2005), grounding (Schoonenboom, 2008), and so forth in online CSCL environments. Furthermore, Wecker and Fischer (2007) have examined fading the structure by adapting and gradually reducing the specificity of prompts according to the contributions of individual participants, in combination with distributed monitoring and feedback by partners during collaboration.

These examples illustrate the breadth and variety of learners, subject areas, environments and approaches that have been attended to by scaffolding research. They also demonstrate the enormous shift that has taken place in the ways in which researchers interested in using technology to support learning use the term scaffolding. None of these approaches to scaffolding are necessarily mutually exclusive and they are combined within some systems. However, the original focus on the diagnosis of learner need, the provision of assistance and the fading of that assistance, that were essential to the original conceptualization of scaffolding, are absent from many contemporary software scaffolding applications.

In contrast to the breadth and variety that can be seen in the learners, subject areas, environments and approaches that have been explored as part of scaffolding research, there has not been a great change in the nature of the technology that has been used and most of the scaffolding with technology research has continued to use fairly conventional technologies and has not embraced pervasive, mobile, ubiquitous and tangible technologies. Work such as that conducted by Nussbaum, 2009; and Looi et al., 2009, that uses mobile technologies represents an encouraging exception. Personal, portable, and wirelessly networked technologies are moving us into a new phase in the evolution of technology-enhanced learning (TEL), namely, seamless learning. It forges mobile learning spaces, and the continuity of the learning experiences across different scenarios or contexts (Looi, Seow, Zhang, So, Chen, & Wong, 2010; Frohberg, Göth, & Schwabe, 2009). The application of mobile technologies to the design of learning encompasses facilitating and scaffolding student-centered learning activities in both formal and informal settings. They provide 'context-aware' tools, reference tools, representational tools, analytical tools and communication tools, which serve as distributed resources for learner collaboration activities.

Beyond Scaffolding research there is a growing body of research that uses mobile, ubiquitous, tangible and pervasive technology in novel and interesting ways to support learning. For example, RoomQuake and WallCology (Moher et al, 2005; 2008) in which a range of technologies are used to embed the learners' experiences across a variety of the elements of their physical environment. Research that is exploring the use of tangible and embedded technologies to support learning (Stanton-Fraser, 2007; Marshall et al, 2009 for example) rarely involves scaffolding in the traditional sense, although several researchers have suggested that there may be the potential for such artefacts to scaffold learning (Luckin et al, 2003, O'Malley & Fraser, 2004; Cassell, 2004).

Within both Scaffolding research and research that explores the use of mobile, pervasive, ubiquitous and tangible technology there is a lack of progress with respect to theory development. Useful attempts have been made to organize scaffolding research. Reiser (2004), for example, draws a distinction between software scaffolding approaches that aim to structure the learner's task and those approaches that shape the learner's performance and 'problematize' the task. He envisions the two approaches — structuring and problematizing — working together to scaffold learners. Quintana and colleagues have developed a Scaffolding Design Framework for science inquiry (Quintana et al, 2004; Quintana & Fishman, 2006). The focus is upon the provision of scaffolding support for science inquiry activities and is based upon some key scaffolding processes for science inquiry, it does not however address the problem of fading. Research that explores the use of mobile, pervasive, ubiquitous and tangible technology also suffers from under-theorization about the nature, process, and outcome of learning (Sharples et al., 2005, 2007); a lack of models and frameworks that specify the relationships between learning and tangible technology (Luckin, 2010; Price et al, 2008); and a lack of understanding about the kinds of characteristics learners are expected to possess in terms of nurturing lifelong learning dispositions. In addition, our understanding of the all important concept of *the learner's context* has not been sufficiently developed to produce models that can support a conceptualization of scaffolding that encompasses the breadth of people, places and artefacts with which a learner interacts, that can be connected through technology, and that might be better used to support and scaffold learning.

The Importance of Context

Previous research, some of which has emanated from research into scaffolding, has confirmed the importance of looking at the *context* of a learner's interactions (Wood, Underwood & Avis, 1999). However, this research has been largely limited to specific environmental locations, such as university lecture halls, school classrooms or 'the workplace'; and it has rarely focused upon teachers as learners. Such an approach limits consideration to just one of the many environments with which and in which a learner interacts. It can also encourage a view of context that conceptualizes it as a container (Cole, 1996), rather than as something that connects our learning experiences together and helps us to make sense of our experiences.

Context is a concept that is discussed across many disciplines and from a variety of perspectives: geography, architecture, anthropology, psychology, education and computer science, for example. It is however possible to identify common themes that transcend these disciplinary boundaries and to arrive at a definition of context that can be used as the basis for exploring learning contexts. Such a definition can support the development of technology-rich learning opportunities that take advantage of the potential afforded by the wide range of evolving ICTs. It can also act as a starting point for the integration of scaffolding across multiple physical and virtual spaces, multiple knowledge domains, multiple time periods and with multiple collaborators. The provision of such a definition is not an easy task, context is a complex concept (Nardi, 1996) and very difficult to 'pin-down' in a way that enables it to be used as the basis for informing design.

Much of the literature about context and space is not specifically about education and learning, and yet it deals with issues, such as institutions and social interaction that are fundamental. Context is portrayed as complex: a dynamic entity that is associated with connections among people, things, locations and events in a geographic and temporally situated narrative. Discussions that link context to space and place are frequent and we see space portrayed as a container within which people and artefacts can be usefully related to one another; and place as a more immediate entity that is framed by form, function, human interactions, design and legislation; and defined by power, policy and politics (Casey 2001:683 for example). The proliferation of ubiquitous ICT adds to the complexity of discussions of context and supports the integration of concerns with the built environment and with the digital environment, or the blended physical and digital environment: 'The proliferation of the microchip renders the everyday spaces of our existence alive, capable of interacting and reacting to our passage' Kerckhove & Tursi (2009:53). For some context is not a singular entity, but rather a multiplicity to which we are serially exposed. Cummins et al (2007) who suggest that in order to make progress, future research should consider 'individual exposure to multiple "contexts" in time and space'.

From a social sciences perspective, Michael Cole's (1996) text on cultural psychology is particularly helpful with respect to context: a term that he suggests is 'perhaps the most prevalent term used to index the circumstances of behaviour' (Cole, 1996: 132). He distinguishes between 'two principal conceptions of context that divide social scientists' (Cole, 1996: 131): the first conceptualization is as 'that which surrounds'. This way of talking about context separates the activity being studied from the influences surrounding it and is open to the criticism that context is portrayed as a container for an activity or event, rather than context being part of the same situation. The second conceptualization of context discussed by Cole is one that builds on a metaphor of weaving, which requires that we interpret mind in a relational way: 'as distributed in the artifacts which are woven together and which weave together individual human actions in concert with and as part of the permeable, changing, events of life' (Cole, 1996: 136).

This attention to the distribution of mind across connected artefacts in the world is echoed in the situated approaches to cognition and learning (for example, Brown, Collins & Duguid, 1989; Brown, 1990) and the Legitimate Peripheral Participation thesis (Lave, 1988; Lave & Wenger, 1991). Likewise, the work of Vygotsky (1978; 1986), whose socio-cultural approach influenced, amongst others, the work of Cole as discussed earlier, resonates with a conceptualization of context that adheres to the notion of a weaving of mediated experiences. The basic ideas of Vygotsky's approach are presented in the 'general law of cultural development', which makes explicit the link between the external activity of the 'interpsychological' activity of the individual's culture, and the 'intrapsychological' processes within the mind that allows the internalization of the higher mental processes from their social origins. They are also the foundation upon which the notion of scaffolding is built.

Theories to Support the Further Development of Scaffolding

One way of exploring how scaffolding might be developed in a manner that addresses the need for a 'learning sensitive' dimension to the developments in 'context sensitive' computing, seamless learning and beyond is to develop models of a learner's context that can inform design. Little work has explicitly attempted to model a learner's wider context and the role of technology. Some work within the open learner modelling community has considered lifelong learner modelling (Kay 2009), while some has considered the use of mobile technology to model mobile learning behaviour (Sharples et al. 2007). A broader perspective finds some useful ideas, such as the Locales Framework (Fitzpatrick 2003) from that attempts to capture the complexity of the real world in an abstraction that can be used to support the design of CSCW technology. It is about the workplace rather than education, but it acts as a useful touchstone for modelling the complexity of a learner's context.

The locales framework (Fitzpatrick 2003) was motivated by the author's desire to find a way of understanding the requirements of complex social situations and design software systems to support such situations. The framework is a shared abstraction and a common language for both those who want to understand the complex social world of work and those who want to design technology support. The framework is built on the premise that designing a socially embedded system is a 'wicked problem'. Wicked problems are not clearly defined and nor do they have a definite solution; a 'good enough solution is the realistic goal' (Fitzpatrick 2003). Fitzpatrick suggests that there is a co-evolution of problem definition and solution when wicked problems are involved and when no clear rules for deciding when the solution has been reached. This type of problem is common in social situations, such as learning. The aim of the locales framework is to support both the increased understanding of complex wicked problems and the system design for wicked problem solutions. The work is clearly relevant to the development of technology-rich learning environments. It is also an interesting example of increasingly common situations where taking an interdisciplinary approach is fruitful. Fitzpatrick's work is aimed largely at the CSCW community, yet it possesses clear and useful parallels to education. Fitzpatrick's work is both theoretically grounded in other work from within CSCW and empirically grounded in Fitzpatrick's experience of system design and workplace study. It is based on a metaphor of 'place' in recognition of the way people construct 'places' through their interactions with spaces (also described as sites) and things; the resources (also described as means) through which people achieve their work. The emphasis of the locales framework is on place and work, nevertheless, this work offers a useful model that might be adapted for a focus on learning and interaction.

Research into mobile learning can also offer some potentially useful work. Sharples et al. (2007) offer an interesting model of context to discuss a theory of mobile learning that encompasses portable technology and the mobility of people as they learn. They suggest that traditional classroom learning is built on the illusion of a stable context. They suggest that mobile learning removes the fixed elements of the learner's situation that allow this classroom illusion, 'creating temporary islands of relatively stable context'. Learning is 'characterized as a process of coming to know through conversation across continually re-constructed contexts' (Sharples et al., 2007: 231). As with many existing mobile learning research (Waycott, Jones, & Scanlon, 2005; Zurita & Nussbaum, 2007; Liaw, Hatala, & Huang, 2010) Sharples et. al. ground and conceptualize the application of mobile technologies to learning in the framework of activity theory. Activity theory views learning as a cultural-historical activity system, mediated by tools that both constrain and facilitate the learners in achieving their learning goals (Sharples et al., 2005, 2007). They distinguished two layers of tool-mediated activity: the semiotic layer and the technological layer. The technological layer represents learning as an engagement with physical tools such as computers and mobile devices that function as interactive agents in the process of knowledge construction. Learning is seen as a semiotic system in which the learner's object-oriented actions are mediated by cultural tools and signs (e.g., language and rules). At the semiotic layer, social interaction occurs mediated by the use of technology as representational tools. CSCL happens in the context of interactions and social scaffolding between and amongst mobile learners. Sharples et al.'s model is built on the belief that learning is driven by conversation. They propose that Laurillard's conversational framework can be used more broadly with other age groups and settings. An adapted conversational framework stresses that conversations take place at the level of actions, involving the performance of an activity, and at the level of descriptions, when learners and collaborators talk about their actions to make sense of them. Sharples et al. state that each individual member of such conversations is located in some physical reality and, therefore, in addition to a need for the constant negotiation of the language of communication, there is also a need to constantly negotiate the context of these conversations. To this end, they propose their model of context and learning: the 'activity system of mobile learning'.

The Ecology of Resources approach (Luckin, 2010), builds upon this previous modeling enterprise and offers a learner-centred definition of context that recognizes both the subjective and the objective nature of learner's experiences with the world, the interconnectedness of all the elements with which people interact and the way in which these interactions shape their understanding of the world. In this model, a person's context is made up of the billions of interactions that they have with the resources of the world: other people, artefacts and their environment. These resources provide 'partial descriptions of the world' which help the learner to construct a distributed understanding of the world that is crystallized with respect to a particular individual through a process of internalization. The Ecology of Resources model is offered as an abstraction that represents part of this reality for a learner, an abstraction that can be shared between social and technical researchers and practitioners to support analysis and to generate system design. It is grounded in an interpretation of Vygotsky's Zone of Proximal Development, is concerned with learning and considers the resources with which an individual interacts as potential forms of assistance that can help that individual to learn. These forms of assistance are categorized as being to do with Knowledge and Skills, Tools and People and the Environment. These categories are not fixed, but rather offer a useful way to think about the resources with which a learner may interact and the potential assistance that these resources may offer. The Ecology of Resources model is used as the basis for a design framework that has been and continues to be used to develop technology rich learning experiences with learners and teachers within and outwith formal education.

The Challenge

The diversity of approaches that have been labeled as scaffolding has led to a variety of opinions and suggestions about how we might best proceed. Some researchers propose that we look at the ways in which different communities have used the scaffolding concept in order to further develop its theoretical foundations (Davis & Miyake, 2004). Others suggest that we need to look back at the origins of scaffolding and, in particular, to Vygotsky's conception of learning (Pea, 2004; Puntambekar & Hübscher, 2005). There is a growing body of opinion that fading is a fundamental and intrinsic component of scaffolding (Pea, 2004; Lahore, 2005; Puntambekar & Hübscher, 2005), and that a line needs to be drawn between scaffolding with fading and scaffolding without fading. And suggestions about the benefits and challenges of casting our scaffolding net wider. Puntambekar & Kolodner (2005) for example use the term 'distributed scaffolding' and draw our attention to the increased complexity that occurs when scaffolding is distributed and also to the potential for distributed scaffolding to offer learners more scaffolding opportunities. Tabak (2004) also explores complex settings and distributed scaffolding and offers a vision of 'synergistic scaffolding', through which learners can take advantage of different types of support provided by different means in an integrated manner, in order to solve complex problems. To make the task of theory development and design framework specification more difficult with respect to the use of ubiquitous, tangible and pervasive computing and to support a more distributed approach to scaffolding, the relationship between theories, models, and the development of learning activities and frameworks for their design is complex and the use of terminology is often inconsistent (Conole et al. 2005; Luckin, 2010).

There are important questions that need to be answered if the body of research on scaffolding with technology is to offer a sustainable basis for developing support for learning in technologically complex environments. For example:

- Are all the opinions about scaffolding useful and can they be integrated into a method for probing our scaffolding research legacy or do we need to differentiate between them, argue against some of them and/or come up with something new?
- Are we avoiding tough questions about fading, because new technologies make it hard, or do new technologies enable us to support learners in different ways that mean fading is no longer necessary?
- Should we refine what we consider to be scaffolding and re-visit its roots in Vygotsky's ZPD?
- Can we explore and refine how we can integrate scaffolding to explore the relationships between the resources that a learner brings to their interactions?
- Can we identify the contingencies for scaffolding across multiple technologies, places, people and domains?
- Should we broaden the scope of learner activity in a similar manner to that proposed by those who favour distributed scaffolding, but taking away the classroom boundaries and considering the learner and their interactions more holistically?

In this symposium three speakers: Sadhana Puntambekar, Rosemary Luckin and Joshua Underwood, will consider the manner in which research in scaffolding can help us develop theoretically inspired pedagogical frameworks that will meet the needs of contemporary learners; and three speakers: Danae Stanton Fraser, Chee Kit Looi and Wenli Chen will discuss the possibilities and challenges of supporting learners with pervasive and mobile technologies.

Sadhana Puntambekar will discuss the notion of distributed scaffolding and how it applies to supporting students in a classroom. She will discuss how a system of scaffolding can address the complex nature of providing support to multiple students in a classroom. In earlier work she (Puntambekar & Kolodner, 2005), introduced the term distributed scaffolding to refer to the variety of support provided in the complex environment of a classroom. Her research found that multiple forms of support—distributed across available tools, activities, and agents in the classroom and integrated in ways that admit redundancy—enhance the learning and performance of a wide variety of students. In a complex classroom environment, it can be difficult to align all the affordances in such a way that every student can recognize and take advantage of all of them. When support is distributed and integrated and takes multiple forms, it is more likely that students will notice and take advantage of the environment's and activity's affordances. She will discuss how distributed scaffolding relates to the key features of scaffolding, grounded in sociocultural theories of learning. She will revisit the roots of the notion in Vygotsky's theory in the context of supporting students in a classroom.

Rosemary Luckin and Joshua Underwood will explore how a redefinition of context from a learning point of view can help us to conceptualize learners and learning in a manner that taps into the intelligence that is distributed amongst the multitude of resources that learners encounter. They will present the Ecology of Resources approach (Luckin, 2010) to stimulate discussion of scaffolding across multiple technologies, people and places. Their presentation will draw upon empirical evidence of learners, teachers and designers using the Ecology of Resources design framework to develop their use of technology to support both science and language learning. The aim being to work towards a way in which we can unpack the manner in which distributed fading might be operationalized.

Danae Stanton Fraser will draw upon examples from a variety of research that involves a range of technologies, including the use of sensor technologies for mass participation in environmental monitoring; urban design and pervasive systems; and e-science, to explore the 'loose' notion of scaffolding often used within the field of mobile and ubiquitous learning. She will reflect on a research agenda to examine scaffolding as part of an integral approach to designing mobile and augmented reality environments.

Chee-Kit Looi and Wenli Chen will explore the perspective of the scaffolding bridging the gap between abstract or general CSCL design principles and the design and enactment of concrete CSCL practices. In their three-year design research study with Singapore schools, they introduced GroupScribbles (GS) technology coupled with appropriate pedagogical graphic organizers to scaffold effective collaborative learning in the context of second language students' vocabulary learning in Singapore classrooms (Looi, Chen & Ng, 2010; Chen, Looi & Wen, 2011). Every student has a mobile device in which they can share and organize ideas through virtual sticky notes which can be posted post anonymously and moved about in private, small-group and full-classroom display spaces.

The graphic organizers were designed to alleviate the problem by changing the nature of the vocabulary learning task through highlighting the key disciplinary content and strategies for vocabulary learning. They can scaffold vocabulary learning by "channelling and focusing" (Pea, 2004). In the GS activity, the organizers help to reduce the degrees of freedom for the task by providing constraints that increase the likelihood of the learner's effective action (focusing on all key components of vocabulary learning such as the meaning, structure, homophones, similar characters, uses in authentic sentences etc). In our interview with one teacher, she expressed her view: "[with the graphic organisers] as time goes on, not only can students' interest of Chinese characters learning improve, they can internalize these strategies to learn Chinese vocabulary. They can also apply these strategies when they come across a new character or word. After some time, the students may no longer need these tangible scaffolding organizers anymore because they have learned what to do when they learn other new characters or words". Thus, the teacher's view is consistent with the expertise reversal effect (Kalyuga, Ayres, Chandler, & Sweller, 2003). When equipped with graphic organizers to help students plan and organize their problem solving, a general technology tool like GS is transformed from a general tool for enabling seamless interactions to a scaffolded software tool integrated with pedagogical design for supporting specific learning, by problematizing important disciplinary content. The distributed nature of the scaffolding is reflected in the support that is distributed across the GS tool, the graphic organizers, the artefacts created, and the different levels of interaction at the individual, intra-group and inter-group levels.

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