Running Head: SCAFFOLDING ACROSS MULTIPLE LEVELS

Distributing Scaffolding across Multiple levels: Individuals, Small Groups and a Class of Students

Problem-Based Learning (PBL), widely used in medical schools, where small groups of students work collaboratively on diagnosis of a medical case, is marked by collaboration, application of knowledge to complex problems, close coupling of learning of the content with strategies for lifelong learning, and self-directed learning under the guidance of an expert facilitator.

The PBL tutorial process starts with a complex problem that students solve in small groups with an expert facilitating the problem solving process. Students start with analyzing the problem, identifying the *facts* and making a list of the *learning issues* i.e., the "knowledge deficiencies related to the problem" (Hmelo-Silver, 2004). Collaboration and self-directed learning are the key aspects of the tutorial process, as students engage in a hypothesis-driven reasoning process in which they continually refine their understanding of the problem, apply new knowledge and eventually find a solution to the problem.

In PBL contexts, self-directed learning is undertaken by each member of the group, and the group as a whole. Students work on solving a complex problem collaboratively, and engage in self-directed learning with support from the facilitator. As such, group members play a crucial role in helping each other learn. As they solve the problem, students find information and read from resources, support their theories, reason using the information they found, present alternative theories, ask clarification questions of each other, concur when they agree with the theories presented by a member of the group, present information, clarify uncertainties, and eventually converge on a solution to the problem. Group members make extensive use of the whiteboards, on which they note down *facts, ideas, questions* and *learning issues* (Hmelo-Silver & Evenson, 2000), as they solve a complex case or problem. Students go back and revise the information on the whiteboards, which helps them have a group memory of the evolving hypotheses, reasoning, and solution ideas.

The expert PBL facilitator helps move the discourse forward by using a range of strategies (e.g., Glenn, Koschmann & Conlee, 1999; Hmelo-Silver & Barrows, 2006; Hmelo-Silver & Barrows, 2008). The role of the facilitator is crucial in that she provides support in many ways such as–summarizing key points in "preceding" talk; asking a question if students seem uncertain of their response, raising issues that could question students' assumptions, allowing students to move on to next set of issues when they are in the right direction such as when assumptions are supported or when theories are validated, and revoicing students' comments. While the facilitator does not provide answers, she has the required content knowledge to ask questions that help move the group's thinking, and guide the groups in ways that moves them closer to the problem solution.

Problem-Based Learning provides a rich environment for learning because it gives students opportunities to collaboratively solve a complex, authentic problem and engage in self-directed learning. Further, it provides opportunities for reasoning, negotiating meaning and using resources for learning of the content. As such, PBL has been adapted and used in several contexts, including helping students learn science in middle schools. However, middle school students grappling with a complex problem and engaging in the kind of reasoning undertaken by adult learners presents challenges for both the learners and the teachers involved. Most important, a major challenge is the "lack of a sufficient number of skilled facilitators" (Hmelo-Silver, 2004, p. 261), especially for the kind of expert facilitation provided to each group in PBL contexts. Students therefore need several forms of support to engage in collaborative problem-solving and be able to learn the content necessary to solve the problem; support that is way more than what a teacher facilitator can provide by herself. Not surprisingly, there have been attempts to design *scaffolding* to foster learning when PBL is adapted for use with younger learners. In this chapter I will discuss one such adaptation–Learning-By-Design (LBD) project (Kolodner, et al., 2003), in which students learn science by solving a design problem.

But before I discuss LBD, I will discuss the notion of scaffolding grounded in sociocultural theories of learning. I will then discuss PBL facilitation from a sociocultural perspective and the similarities in the PBL tutorial process and the scaffolding construct. Following this, I will discuss how we supported students' learning in LBD classrooms and introduce the notion of distributed scaffolding. Finally, I will discuss implications for implementing PBL in contexts where more support for collaborative and self-directed learning are needed.

Scaffolding and Facilitation

Scaffolding Students' Learning

The concept of scaffolding is associated with Vygotskian sociocultural theory (Vygotsky, 1978). A key theoretical construct often linked to the notion of scaffolding is the Zone of Proximal Development (ZPD), defined by Vygotsky as "distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance and in collaboration with more capable peers" (p. 86). According to sociocultural theories, learning is seen as a social activity that takes place under expert guidance, mediated by tools, routines, resources and activities, to enable a learner to move ahead within her zone of proximal development (see Tudge & Scrimsher, 2003). A learner's capacity to bridge this gap between the actual and the potential depends on the kinds of support provided. Instruction in the ZPD is often viewed as providing assistance, or *scaffolding*, to enable a child or novice to solve a problem, carry out a task, or achieve a goal that he or she would not be able to achieve independently. While there has been some discussion about how scaffolding relates to learning within the ZPD (e.g., Tudge & Scrimsher, 2003; Chaiklin, 2003), for the purpose of this chapter, I embrace the view that scaffolding is a way to operationalize interactions within the ZPD (Wells, 1999; Campione, Brown, Ferrera, & Bryant, 1984; Rogoff, Malkin, & Gilbride, 1984; Greenfield, 1984).

Research suggests that scaffolding students' learning within the ZPD has some key features. First, *human mediation* is at the center of learning in Vygotsky's theory, where interactions that are key to learning are said to occur at the interpersonal level first, before they are internalized at the intrapersonal level. But just as important is a second type of mediation and that is symbolic mediation. According to Kozulin (2003), symbolic mediators range from primitive tools (e.g., tying knots) to higher order cognitive tools consisting of "signs, symbols, writing formulae, and graphic organizers" (p. 23). Kozulin emphasized that both forms of mediation are crucial; for symbolic mediators to be used appropriately, human mediation is essential.

Second is the notion of *intersubjectivity* (Rogoff, 1990; Wertsch, 1985). Werstch (1984) explains that learning in the ZPD involves a complex process as the child and the adult have different "situation definitions" of the task. Intersubjectivity is attained when the adult and child collaboratively redefine a task so that there is combined ownership and the child shares an understanding of the goal that needs to be accomplished. The adult's role is to ascertain that the learner is invested in the task and to help sustain this motivation, "making it worthwhile for the learner to risk the next step" (Wood, Bruner & Ross, 1976, p. 98). What happens during learning, is a qualitative restructuring in which the child redefines the situation, a "*situational redefinition*" (parentheses in original), as Werstch (1985) puts it.

A third key feature is the provision of appropriate support by the adult based on an *ongoing diagnosis* of the child's current level of understanding. To achieve this, the adult needs a thorough knowledge not only of the task, its components, and the subgoals to be accomplished, but also of the child's changing capabilities as the instruction progresses. Fourth, the ongoing diagnosis of the child's current level of understanding leads to a *careful calibration of support* (Stone, 1998a). The adult draws from a repertoire of methods and strategies to provide graduated assistance, which is constantly fine-tuned based on the child's changing knowledge and skills. Thus, the adult's strategies differ not only for different learners, but also for the same learner at different times. The adult may model the ideal solutions (Wood et al., 1976) or the appropriate strategies (Palincsar & Brown, 1984) or provide several types of support, such as offering explanations, inviting participation, modeling desired behavior, and providing clarifications (Roehler & Cantlon, 1997).

A fifth key feature is *fading* the support so that the learner can be in control and take responsibility for learning. As cognitive processes move from an interpsychological to an intrapsychological plane—a process Vygotsky (1978) called *internalization*—

responsibility transfers from the teacher to the learner, and the scaffolding can be removed. This transfer of responsibility requires the child not only to learn how to complete a specific task, but also to abstract the process of completing the task in order to generalize this understanding to similar tasks (Wood et al., 1976), so that le learner can function independently.

Facilitation in PBL contexts

The role of the facilitator has been widely discussed in PBL contexts and indeed, the facilitator plays a crucial role during the tutorial process, helping the hypothesis driven reasoning for the group to move forward while grappling with a complex problem (e.g., Barrows & Tamblyn, 1988; Hmelo-Silver & Barrows, 2006). In the section, I will discuss how the tutorial process during PBL embodies the core elements of scaffolding. Table 1 summarizes the key aspects how the PBL tutorial process maps on to the key tenets of scaffolding students' learning summarized in the previous section.

The foremost element of learning from a sociocultural perspective, as discussed earlier, is that learning occurs under the guidance of an expert tutor in which the tutor supports the novice learner in a form of cognitive apprenticeship (Collins, Brown & Newman, 1989). Similarly, tutorial interactions are at the core of the PBL process, and an expert facilitator works with a small group of students as they solve a complex problem. Rather than providing direct instruction in the content that students are learning, the facilitator instead asks expert questions that lead the students to reason, test their hypotheses, and eventually come up with a solution to the problem.

Additionally, in PBL, learning not only occurs through social interactions, under the guidance of an expert tutor, but is supported by tools, resources, symbols, routines and procedures, that are typical of a culture, for example, the diagnosis procedure in the medical community. This is another key aspect of learning within the ZPD in that students are supported "to engage in the activities, talk, and use of tools in a manner that is consistent with the practices of the community to which [they] are being introduced (e.g., scientists, mathematicians, historians)" (Scott & Palincsar, 2009, p. 854). The whiteboard, integral to the tutorial process, works as a common artifact that is constantly updated as students engage in discourse and reasoning typical of their community.

Scaffolding	**PBL Process**
Intersubjectivity or shared understanding	Problem understanding and refining throughout the tutorial process
Use of human and symbolic mediations: tools, resources and routines of a culture	Use of whiteboards, strategies and reasoning procedures of a community (e.g. medical professionals)
Ongoing diagnosis and calibrated support	Prompting, revoicing and questioning by the expert facilitator tailored to the group's progress
Fading of support by the expert, as the learner internalizes the content as well as the strategies	Fading of support with a focus on lifelong learning and application of knowledge and skills to new problems

Table 1: Scaffolding and the PBL Process

In PBL contexts, intersubjectivity, i.e., shared understanding, occurs at multiple levels and at multiple times between group members, and between the tutor and the group, as hypotheses are refined and the problem understanding is revised. As students gain experience in the hypothesis driven reasoning, and gain content knowledge, they revise their hypotheses about the patient's illness. In PBL, shared understanding is critical not only for initially understanding the problem, but at each stage during the hypothesis generation and reasoning, as the facilitator works with the group to identify new issues, and helps them move toward a solution. Thus in a sense, the situation definition, i.e., the student's understanding of the problem is refined on an ongoing basis as students gain more knowledge to help them solve the problem.

The tutor provides scaffolding based on an ongoing diagnosis of the group's progress and employs many strategies to help with the reasoning process, "knowing when an appropriate question is called for, when students are going off-track, and when the PBL process is stalled" Hmelo-Silver, 2004, p. 245). Hmelo-Silver (2004) found that the facilitator engages in metacognitive prompting to help students provide causal explanations and revise their hypotheses, and often tailors her strategies not only to different groups, but also to the different stages of the PBL process. Thus the facilitator uses a flexible set of strategies, changing them as the situation demands, and finally fading some of the support as the group gains experience in the PBL methods and also gathers more content knowledge.

As I have discussed in this section, the PBL tutorial process has substantial overlaps with the classical notion of scaffolding, in which an expert works with a learner or with a small group of learners. However, when PBL is used in middle school classes, this process of scaffolding needs to be revised in several ways, which I will discuss in the next few sections.

PBL in Middle School Science Classrooms

PBL has been widely used in medical schools and in other areas in college-level classes, and it has also been adapted to foster learning in middle schools. While the benefits of PBL to foster reasoning skills and lifelong learning skills in college age learners have been widely discussed (Hmelo-Silver, 2004), researchers have also pointed out challenges for productive learning in PBL settings, especially when it is transported into K-12 settings (Ertmer & Simons, 2006). The most significant challenges reported in research pertain to expert facilitation, self-regulated learning and collaborative learning.

In the medical school environment, an expert facilitator works closely with a small group of students. This kind of close small group facilitation is not possible in other environments where one facilitator is often in charge of several groups. In such situations, multiple groups may be managed using what Hmelo-Silver called wandering facilitation, i.e., one facilitator moves from group to group. This strategy may be useful in higher education settings, but challenging in K-12 settings, where students are not used to the kind of independent learning that is required. In K-12 settings, a single teacher is unable to provide assistance to groups at a time when they need it, as when they are facing difficulties moving forward in their problem solving process.

A second challenge is that PBL requires students to be skilled self-regulated learners, being able to monitor their own learning. To be self-regulated learners, students need to be able to continually set learning goals, develop strategies for reaching the goals, monitor their understanding, and change strategies as needed (e.g., Azevedo, Cromley & Seibert, 2004). Research suggests that engaging in the PBL process which requires a great deal of reflection and monitoring of self learning is a challenge even for adult learners (Evensen, Salisbusry-Glennon, & Glenn, 2001). For younger learners in K-12 settings or for learners with poor self-regulated learning skills, providing appropriate scaffolding as needed is therefore central to successful learning.

The third challenge is that PBL requires that students be able to collaborate with group members. Effective collaboration, knowledge negotiation, and joint knowledge construction is a key aspect of PBL. However, research in collaborative learning suggests that very often students are known to work *in a group* but not *as a group* (Mercer & Littleon, 2007), and that especially younger learners need a lot of support to be able to engage in the kind of collaborative learning required in PBL. Even adult learners in PBL settings may not know how to collaborate effectively (Evensen et al., 2001).

Indeed, each of these issues were evident in the implementations of Learning By Design which lead to a rethinking of how scaffolding might be designed for learners in middle school science classes.

Scaffolding Learning By Design

Learning-by-Design is informed by the cognitive model that comes from Case-Based Reasoning (Kolodner, 1993; Schank, 1982; Schank, Berman, & Macpherson, 1999), and it was influenced greatly by the practices of Problem-Based Learning (Barrows, 1985; Koschmann, Myers, Feltovich, & Barrows, 1994). In a LBD unit, all the students in the class are given the same design challenge, and students work in teams of 3 or 4, each team attempting its best design solution. As in PBL, teachers take on the roles of facilitators, orchestrating the movement from teamwork to whole-class discussions and presentations, managing discussions and helping students summarize important aspects of the issues being raised. Whole-class discussions focus on identifying what students already know, issues they need to learn more about, ideas for addressing the challenge and plans for moving forward, as well as discussions of the science being learned and how it might be applied. Doing and reflecting are interleaved with each other, and frequent returns to the whiteboard help students maintain their perspective on the design problems.

In one of the early implementations of LBD in middle school classrooms, students were asked to design a model of an arthropod-robot. The idea was to help them understand arthropods, as part of their life science curriculum. Much of the scaffolding provided in this study was modeled around the facilitation during Problem-Based Learning. Students worked in small groups and were asked to record facts related to the problem, their ideas, learning issues and any questions that they had. Teachers served as facilitators, helping students' reason about and summarize important aspects of the discussions. The teacher facilitated whole-class discussions to help groups report on what they were learning. Notes from these discussions were recorded on PBL-inspired white-boards that were posted for all students to see.

But similar to the open-ended problems in PBL, design problems are complex, requiring a range of skills and capabilities. Designing entails the integration of several skills (Lehrer & Romberg, 1996) such as analysis, synthesis, evaluation, and revision. Good design problems have multiple solutions, requiring students to generate a set of criteria and evaluate alternative solutions. Iterative design of an artifact requires students to incrementally construct, evaluate, discuss and revise both the models they are designing and their conceptions of the science they are learning. Further, adult learners engaged in PBL, such as when students are solving a complex medical problem, are better prepared for the self-directed learning that PBL requires. Our early implementations showed that students needed more support than what a teacher could provide in a classroom (Gertzman & Kolodner, 1996; Gray, Young, & Newstetter, 1997).

Early LBD studies showed that middle school students do not have the experience to engage in the kind of self-directed learning and reasoning that is typical in PBL contexts in higher education (Hmelo, Holton, & Kolodner, 2000). Specifically, they needed support at three levels: First, we found that steps in the design process itself had to be scaffolded, for each student *individually*. Students needed support to successfully execute the various activities involved in designing – analyzing the situation to understand the problems and issues that needed to be addressed, gathering information, generating alternative solutions, generating criteria to evaluate solutions, thinking about trade-offs and justifying choices. Even with PBL-like facilitation, the range of decisions they needed to make to move forward overwhelmed them, and they had difficulties with the reasoning involved in learning from design. This made the collaborative learning in groups difficult, because students were unable to think through the issues on their own and contribute to the group.

Second, at a *group* level, students were not used to the kind of collaborative learning expected of them. They were not used to questioning each other and building knowledge as a group (Puntambekar, Nagel, Hübscher, Guzdial & Kolodner, 1997). They needed specific opportunities that enabled them to critique each other's ideas and those of other groups in the class. Third, at the *whole class* level, students also needed to learn to participate in whole class discussions to share and discuss what they had learned.

Thus, three levels of support needed to be designed for students to learn to solve a complex design problem: individual reasoning and working on the design problem, small group collaboration and learning and whole class discussions. Further, a balance between these three forms of support needed to be found, so that they were all integrated seamlessly. To address these issues, we designed a system of scaffolding, which we call *distributed scaffolding* (Puntambekar & Kolodner, 2005; Puntambekar & Hübscher, 2005).

Distributed Scaffolding

The notion of distributed scaffolding describes a system of scaffolding that helps students through the complex processes in learning to solve open-ended design problems. Scaffolding is provided through a system of several tools and agents and is integrated so that students can take advantage of the different forms of support. In the LBD project, a range of tools were designed to support learning: design diaries for individual and group work; pin-up sessions and online discussion forums to help students present their ideas and critique each others' ideas; and teacher-facilitated whole class discussions to provide opportunities for students to listen to ideas from groups other than their own. Each of these tools played a different role in the learning process because each tool supported different aspects of learning, as discussed below.

The design diaries

We introduced the design diaries to support students' problem solving, by providing prompts for the various stages of solving the design problem. The diaries were based on the critical features of scaffolding described by Wood et al. in that they helped highlight the important steps in the task and provided direction. In addition, they helped break the design task into meaningful sub-goals (Rogoff, 1990). For example, one of the key aspects of PBL is that students generate learning issues that guide their reasoning. But we found that middle school students needed a lot of support to think about learning issues. So we provided them with prompts in the design diaries that helped them think about what they knew about the topic and what questions they might want to ask. Similarly, the diaries had prompts that helped students through the stages in the design process such as generating alternative solutions, using resources to learn science, generating criteria, evaluating solutions using the criteria and finally coming up with a viable solution. Students used the diaries as they worked individually, but the diaries also had "group pages" – pages that provided students with prompts to come together as a group and discuss each other's ideas. For example, when students came up with an initial solution to a problem, a group page would contain prompts for them to think about which solution would best help them solve the problem and decide on one or two solutions that they would like to try. Middle school students often do not have the skills to engage in the reasoning that students in a PBL classroom in higher education typically have, and the teacher cannot provide the fine-grained support that groups of students often need. The design diaries, therefore, helped students as they reasoned about the design process.

Collaboration opportunities

In addition to individual and group work in the diaries, we also wanted to support students' reasoning about the science they were required to learn, by critiquing each other's designs and asking questions, and by justifying their choices. While this type of reasoning might happen more readily in college going learners, we found that we needed to build these opportunities into the curriculum. We provided specific opportunities for students to critique each other's ideas. Research suggests that on the one hand, peers can help each other learn, but on the other, some researchers argue that peers themselves need assistance to engage in the practices of collaborative learning (e.g., Chinn & Chinn, 2009; Mercer & Littleton, 2007). In order to provide students with such opportunities, we introduced “pin-up sessions” in which students displayed their early solution ideas in the classroom. We took the notion of the pin-up session from the architecture studio as a format for these presentations. In an architecture studio, students periodically present their design ideas and sketches to the rest of the class and to their teacher by creating a poster, pinning it to the wall, and then explaining to the class their intentions and how they plan to achieve them. Creation of a presentation encourages students to think through their ideas deeply and make their reasoning clear. Hearing the ideas of others provides opportunities for students to learn what makes for good justifications. During the pin-up sessions, the teacher and their peers questioned students about their ideas and about the science content, thus making them think hard about relating their designs to the science they are learning. We also introduced an electronic discussion tool to help students collaborate asynchronously across classrooms, so that students could critique designs put forth by groups in classes other than their own. We found that presenting their ideas, answering their peers’ questions and considering the ideas of others gave students a chance to think about and refine their own ideas before writing them down. (Puntambekar & Kolodner, 2005; Puntambekar, et al., 1997).

Whole class discussions (teacher facilitated)

As is true of the pin-up sessions, whole class discussions facilitated by the teacher were also encouraged as an integral part of the learning by design classroom. In an LBD classroom, students often worked in small groups. As such, many of the learning experiences were unique to the group, and were not necessarily shared by the whole class unless such discussions were integrated into the classroom activities. To enable sharing of learning experiences across all the groups in the classroom, whole class discussions facilitated by the teacher were integrated. The teacher used the discussion time to reflect on what students had worked on the day before, to introduce students to the day's design activities, and to summarize what they had learned during their design activities. After students had tested their designs and had engaged in a lot of 'hands-on' work, the teacher helped them think about what they had done and recount their design experiences. This structured time for student reflection is extremely important in a Learning By Design environment in which students can easily get lost in the 'doing' and do not necessarily think about how their design activities relate to the science principles they are learning. Integrating whole-class discussions regularly into classroom activities helped students to reflect on and explain their designs in terms of the science they were learning.

Distributing scaffolding

The scaffolding mechanisms mentioned above provided support at individual, group and whole class levels (see Table 2).

Studies in which we implemented distributed scaffolding showed that students had a deeper understanding of the science that they were learning through the design activities (Puntambekar & Kolodner, 1998; Puntambekar & Kolodner, 2005). They were also better able to articulate their design decisions and question each other's designs in terms of the science they were learning. Our results showed that learning science from design activities requires multiple forms of support, distributed across the available tools, activities, and agents and integrated in a way that admits redundancy. In a complex problem-based environment, it can be difficult to align all the affordances in such a way that every student can recognize and take advantage of all them.

Tools and activities	**Processes supported**	**When the tool or activity was used**
Design Diaries	Practices that are part of the design process: defining the problem space, generating criteria, evaluating solutions, etc.	By individuals, as homework or during reflection time; by groups when they filled the group pages
Pin-up sessions and electronic discussions	Justifying solution ideas, generating criteria, asking peers for clarifications and providing clarifications	By groups of students in the classroom, after investigations, after coming up with possible solutions
Whole-class discussions and presentations	Sharing solution ideas, asking questions across classes	By a whole class of students at critical junctures, during solution generation and evaluation

Table 2: Distributed scaffolding

However, when support is distributed, integrated, and multiple, there are more chances for students to notice and take advantages of the environment's and activity's affordances. Additionally, the support provided to students through multiple mechanisms admitted some redundancy, so that students within a range of ZPDs in a classroom context could all take advantage of the different scaffolds. For example, students who fail to take a design diary prompt into account are provided with other opportunities to be scaffolded, such as during a pin-up session when a peer asks the same question that is in a prompt but uses different words or during a whole-class discussion when another student explains how he/she accomplished some task. Together, the tools and resources that we included in our distributed scaffolding system helped students by

- *providing many opportunities to explain, justify claims and reflect on their decisions*
- *providing some structure in terms of preparing for milestones or interim products*
- *being metacognitive about the process while at the same time learning science content*
- *closely tying the content and process so that students learn both*
- *engaging in discussions for integration, reflection and synthesis of content*

The system of scaffolding we put together combined tools, routines and procedures, and recognized the role that peers and teachers played in bringing everything together.

Implications for Implementing Distributed Scaffolding

The original notion of scaffolding assumed that a single more knowledgeable person, such as a parent or a teacher, would help an individual learner, providing him or her with exactly the help he/she needed to move forward. Similarly in typical PBL contexts, the facilitator works with a small group of learners, providing them with the guidance to solve a complex problem. But the modern classroom does not allow for the fine-grained facilitation that can occur with a small group of students on an ongoing basis. In a classroom context, a single teacher is often providing scaffolding for up to 35 students at the same time, usually basing her help not on what any individual requires at the moment, but rather on what she believes the majority of the class needs in order to be successful. With distributed scaffolding, the tools and practices that we developed and implemented allowed us to support students at multiple levels, individual, small groups and a whole class of students, allowing us to support learning at a more fine-grained level.

According to Rogoff, (1999), one way to provide scaffolding is to make the messages sufficiently redundant so that if a child does not understand one aspect of the communication, other forms are available to make the meaning clear. In her studies of weavers in Mexico, Greenfield (1999) also emphasized the importance of the multimodal assistance that mothers provided to their daughters who were learning to weave. In a classroom, it is not possible for one person to provide support for the multiple students learning at different rates within their ZPDs. Building redundancy by designing multiple tools, can therefore make up for the lack of graduated assistance in a single tool, if multiple ways and multiple levels of scaffolding are tailored to the multiple ZPDs that are found in any classroom. Rather than looking at a single tool as providing scaffolding, we need to look at a suite of tools as providing scaffolding to students. So even if a particular tool does not change or fade its prompts, the students may no longer need the tool and thereby *the tool itself may be removed*. When scaffolding is provided in multiple formats, there are more chances for students to notice and take advantages of the environment's affordances. If different types of scaffolds are built based on the multiple ZPDs that are found in a classroom, then as students make progress, some of the tools may be removed, thereby achieving fading.

In practice, this requires facilitation and orchestration by teachers, perhaps at a level that they are not used to in traditional lecture-based classrooms. Especially important is for the teacher to recognize how to coordinate the small group and whole class discussions. Often, groups of students tend to have different experiences that need to be shared with the whole class, in a process that requires reflection, synthesis and summarization of major issues. This kind of making the private learning experiences public (Tabak & Reiser, 1997) is crucial in classrooms using PBL and related approaches. As Rojas-Drummond and Mercer (2003) have pointed out, teachers need to facilitate collective thinking and reasoning among students by establishing ground rules to promote dialogue in the classroom. Professional development efforts that focus on strategies that help teachers manage small group and whole class discussions are therefore integral to the success of PBL-like pedagogies.

As we implement pedagogies such as PBL in complex classroom situations, notions such as distributed scaffolding, need to be continually refined to fit particular contexts. Recent research has seen progress on this front. For example, Tabak (2004) presented the related notion of *synergistic scaffolding*, in which different kinds of support, such as software and teacher coaching, are combined to co-occur and interact to address the same learning need in different ways. Luckin (2010) presents the *ecology of resources* approach to describe scaffolding across multiple technologies, people and places.

As we move forward there's another issue that we need to pay particular attention to, the distinction between scaffolding and scaffolds. In recent times, the word "scaffold" has been used to discuss the kinds of support that is provided to learners. For example, Ertmer and Simmons (2006) discuss hard and soft scaffolds, to describe support that is static or dynamic, respectively. However, as Stone has described

> it is important that we keep in mind two interrelated points. First, the term scaffolding serves both as a noun and a verb (Oxford, English Dictionary, 1989). There are entities that serve as scaffolds, such as

diagrams, and these entities serve an important role in instruction. However, what is most crucial is the process by which these entities are used to foster new understandings. In essence, one could argue that the core of the scaffolding metaphor rests squarely on viewing it as a process (Stone 1998b, p. 412).

As we move forward helping students in complex learning environments, it is important to note that while we design tools and resources that serve as scaffolds, it is the process of how the tools agents and resources are combined into a system of scaffolding that crucial for successful learning.

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