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ABSTRACT

One higher education institution initiated a context based, situated learning environment to guide an introductory freshman engineering course that was designed to overcome many problems in traditional engineering education. Instructors used situated environment to facilitate: student acquisition of intellectual curiosity, appropriate framing and resolving of ill-defined problems, and effective communication skills. Students developed solutions to ill-defined problems in astronautical, civil, electrical, and mechanical engineering. The course promoted positive student change, but formative evaluation (faculty interviews, questionnaires, and observations) uncovered problems with scaffolding that detracted from overall course success. These problems included: (1) disregard of its value by some professors at the expense of students lacking prerequisite skills; (2) student confusion regarding inherently vague concepts like reflective judgment and confusing problem-solving tasks; and (3) differing approaches to scaffolding taken by several instructors within the course. Suggestions for solving the problems included: incorporating technology supports into the course; direct instruction on reflective judgment and problem solving strategies rather than repetitive mentioning of catch words; and exposure of instructors to standards of scaffolding as a point of reference upon which to base performance. (Contains 28 references). (SM)

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Realizing the Potential of Scaffolded Instruction in Situated Learning Environments: Lessons from a Formative Evaluation

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Introduction

In the Fall of 1995, a context-based, situated learning environment was initiated at a military institution of higher education to guide an introductory engineering course for freshmen. The environment was situated on the theme of a "Mission to Mars" with students developing solutions to ill-defined problems in three blocks of engineering instruction: "getting there" (astronautical); "siting and construction" (civil); and "living there" (electrical and mechanical). The course was designed to overcome many of the problems in traditional engineering education identified by Law and Marlino (1994, p. 4), including "(1) an emphasis on rote manipulation at the expense of critical thinking skills; (2) a lack of interdisciplinary connections made among topics and concepts studied; and (3) a lack of design expertise early in the program." Instructors used the situated environment to facilitate student acquisition of three educational outcomes: intellectual curiosity, appropriate framing and resolving of ill-defined problems, and effective communication skills.

The situated course designed at this school falls under the philosophical movement of "constructivism" whereby learners actively participate in the shaping of their own knowledge structures rather than passively receiving facts and concepts. Differing perspectives on constructivism and student engagement exist (see Figure 1) and range from mechanistic, exogenous views of dependent learners assimilating information given them, to organismic, endogenous views of independent learners who seek information on their own and accommodate it with pre-existing knowledge into personally relevant constructs (Beed, Hawkins, & Roller, 1991; Moshman, 1982; Prawat & Floden, 1994). At the center of this continuum lies the social, dialectical constructivist movement where interactions between the student, instructor, and environment provide the foundation for learning (Moshman, 1982). Popular social constructivist approaches include cognitive apprenticeships and modeling (Collins, Brown, & Newman, 1991), cooperative learning and reciprocal teaching (Brown & Palinscar, 1989), and scaffolded instruction (Beed et al. 1991) in Vygotskian "zones of proximal development" (Vygotsky, 1978). Considerable overlap between these methods exists with reciprocal teaching employing scaffolding, some cognitive apprenticeships employing reciprocal teaching, etc.

Situated learning environments take many forms with the basic premise being, "students carry out tasks and solve problems in an environment that reflects the multiple uses to which their knowledge will be put in the future" (Collins et al. 1991, p. 487). These environments are popularly referred to as situated cognition (Brown, Collins, & Duguid, 1989; Choi & Hannafin, 1995), goal-based scenarios (Schank, 1992), and anchored instruction (Cognition and Technology Group at Vanderbilt, 1992), and often employ the social constructivist methods just described to facilitate learning in context.

The engineering course promoted positive student change toward the three educational outcomes in its first semester (Reeves, 1996). However, a formative evaluation consisting of faculty interviews, questionnaires, and observations as well as student focus groups, e-mail journals, observations, concept mapping activities, and reflective judgment exercises, uncovered problems with scaffolding detracting from the overall success of the course. This paper describes three problems encountered with scaffolding in this course, posits solutions to mend those problems, and discusses the implications of improved scaffolding on situated learning for each.

The Scaffolding Method

Scaffolding is a technique used by instructors to support learning in zones of proximal development (ZPD). The ZPD is defined as the cognitive capability area in which an instructor should situate their content--the area between a student's ability level to an area just outside of their ability level (Bruning, Schraw, & Ronning, 1995). In social constructivism, tasks and problem situations are introduced for which students lack necessary knowledge and skills. The instructor employs scaffolding techniques while the student constructs mind bridges between pre-existing and new content--preferably in a personally relevant context such as a situated learning environment. The goal is to establish a state of "flow" or intrinsically motivating experiences that occur when learning challenges are approximately matched with skills and are supported by scaffolding (Csikszentmihalyi, p. 100, 1985).

As Beed et al. (1991) describe, there are five levels of instructor scaffolding: (a) teacher models behavior or response, (b) teacher encourages students to participate, (c) teacher directs student attention and provides hints about specific elements of strategies they could employ, (d) teacher names strategies and encourages students to use them, and (e) teacher asks general questions such as, "what might you do at this point...." Responsibility for choosing appropriate strategies and engaging the task is eventually faded from the instructor to the student. The level of instructor scaffolding lies on a continuum, then, from total teacher modeling of the desired behavior or response to eventual fading of help and complete withdrawal of support (see Figure 1).

Problems Encountered with Scaffolding

The Disregard of Scaffolding

Evidence was uncovered during the formative evaluation of the engineering course that some instructors disregarded scaffolding as an important technique. Faculty interviews uncovered a belief by some that scaffolding, or "hand holding" as one noted, was unnecessary. One instructor inferred that students who made it into this reputable institution with high SAT math scores should be independent learners capable of following lectures, reading handout materials, and subsequently understanding complex mathematical material related to engineering.

This viewpoint runs contrary to the fact that students often have varying entry levels and capabilities in specific subject matter domains and topics. In the case of the engineering course under evaluation, students were chosen at random to participate. They may or may not have possessed prerequisite skills in physics and calculus which might be expected from students choosing to take engineering courses under normal conditions. Student responses from e-mail journals and focus groups indicated one third to one half felt they lacked the math skills to successfully frame and resolve the ill-defined problems posed to them. Students responded, "Some [in this class] have not had high school physics, so the material that has been a review for us is completely new for them." Further, some stated that "they are going to have to provide a lot of support for physics for most of the people that don't have the knowledge I have." Finally, one student expressed his frustration, "My biggest complaint was that we didn't have a choice coming in here, that some people like him had calculus or physics, and I think that's what a lot of people needed."

In addition to the lack of attention paid to prerequisite skills, some instructors failed to employ scaffolding correctly as described in Beed et al.'s (1991) five levels. One student indicated:

> They would hand out an assignment and an explanation sheet with it, but they wouldn't go over the assignment until the next period when the assignment was due. But, if you didn't understand the handout, you couldn't do the assignment.

Another student stated "he would give an assignment with dittos..., and it would be due the next class period..., but if he would've explained what he did the day he assigned it, it would've been easier." Perhaps the goal of this instructor was not to make the assignment "easy," but rather to have them explore concepts, think, and try out formulas and equations on their own. Still, fostering independent thinkers can be negotiated via classroom scaffolding as the instructor models desired skills and invites students to try out the task on their own, ask questions, and employ various problem-solving strategies. Further, if undertaken appropriately, the scaffolding process does involve a gradual fading of instructor support toward a more independent learner.

Scaffolding Ill-Defined Problems

A second problem encountered during the engineering course was the difficulty students exhibited in framing and resolving ill-defined problems. According to Reeves' report from a faculty interview (1996, p. 5),

> the faculty observed that significant factors that would add to the complexity of solutions proposed by [students] were often over-looked. The consensus of the faculty was that, although [students] had improved in their ability to recognize problems as ill-defined, there was much room for improvement in terms of the actual problem-solving strategies they used.

Further, student groups made presentations three times during the course to propose solutions to the ill-defined problems. Groups were required to defend their proposals through questioning from other students and faculty. On average, classroom observations indicated students were only able to accurately defend their strategies half of the time. When queried about specifics in their plans, students would often begin their responses with, "I think...," or "I suppose...," or "We just assumed...." It could also be assumed students did little research beyond the minimum required to develop a proposal, they typically based their work on assumptions rather than fact, and did not exhibit reflective judgment (Kitchener & King, 1981) by justifying their solutions systematically.

During focus groups, some students expressed their view that this course, situated around an ill-defined "Mission to Mars," was vague and confusing.

> My problem I've had with it, is that other courses I always know where I'm going. I can look at the syllabus and say, "o.k., this is where I need to go, this is where we're going." This course, you really don't know. You kinda have the general idea, but it's vague what the next assignment is going to be.

Another student mentioned, "we should be able to think for ourselves, but I think the last block with the electrical [engineering] was almost too ill-defined."

Scaffolding in the Classroom

The third problem with scaffolding at this school revolved around the number of instructors teaching the engineering course (five), and their different approaches to constructivism in the classroom. During classroom observations, the degree of negotiated, knowledge-building was viewed differently from meeting to meeting. Occasionally, there were straight lectures with low student engagement (asking few questions, not taking notes) and with instructors not eliciting responses from students. More often, instructors attempted to involve the students by posing questions, calling on students to respond, and then providing feedback such as, "correct," or, "no, does anyone else know?" But this process, known as "IRE," or initiate, respond, evaluate, is more indicative of teacher-dominated discourse than of a constructivist classroom that encourages students to express their thoughts and reflect (Bruning et al., p. 126, 1995). Still, some instructors encouraged students to work on projects in groups, wandered the classroom answering questions, and guided student activity by hinting and prompting at engineering methods particularly well suited for particular problems.

During focus group interviews, some students indicated a preference for instructors with an open-ended, questioning approach:

> I like [Instructor A's] technique or lack of it. He gets up there and says, "o.k., today we're going to figure out how much weight the soil can carry, you have this much and this much, what are you going to do," and you have to kinda sit there and, I don't know, think. It's more interesting than a core course where most of the time it's plug this number here, and turn the wheel, and get an answer out. I kinda like it. [Instructor B's] style was put you number in here, turn a few wheels, and your number comes out.

Other students expressed a preference for negotiated, social constructivism:

> ...they told us to think of a good landing site, and then they developed one for us. I would like more to stick to the students, you know, let the students run a little more of the decision making--make it more like a committee.

Other students, however, indicated a dislike for the dialectical style and a preference for the mechanistic approach, "I'd like it if [Instructor A's] style had a little more technical aspect to it, a few more numbers."

A variety of teaching styles and student preferences for certain styles were iterated throughout the course. While some instructors appeared comfortable with scaffolding and negotiated classroom dialogue by questioning students, others tended to lecture students with technical material. As Laffey (1995) pointed out:

> One of the dilemmas that continues to challenge the faculty and the students is the dichotomy between "hard" content (knowing principles and formulas, doing equations, etc.) versus "soft" processes (learning to work in a team, building problem solving skills, etc.). Of course, there does not need to be a dichotomy, but the nature of our educational institutions and traditions has left us with this model.

Suggested Solutions

The Support of Technology

In the first problem described, instructors were described as reluctant to "hold hands" and scaffold instruction for a classroom of learners with varying levels of prerequisite skills. In their defense, it may be unrealistic for teachers to take into account every student's skill level and construct lessons with appropriate levels of scaffolding for each of them. Therefore, it is suggested here that technology may be employed as a supplemental scaffold when used in combination with an instructor's modeling and prompting of appropriate strategies.

Electronic performance support systems (EPSS) are suggested as one type of technology which could be use to help students frame and resolve ill-defined problems. According to Gilbert and Leighton (1995), an EPSS is an "electronic system that provides integrated, on-demand access to information, advice, learning experiences, and tools to enable a high level of job performance with a minimum of support from other people." (see Gery, 1991, for more information on EPSS technology)

EPSS technology can be utilized as a cognitive tool to support scaffolding in situated learning environments. In the absence of instructor scaffolding when students are outside of class, an EPSS provides an external resource which may be called upon to provide structured information in databases (such as calculus and physics concepts) and opportunities to learn that information via short tutorial experiences. Further, many EPSS systems are designed with on-line coaching to help students proactively set goals toward completing a task and to reactively respond when trouble processing the information occurs (Gilbert & Leighton, 1995).

In recent years, a number of technology scaffolds have emerged to support student inquiry into ill-defined environments. Examples include the Belvedere tools (1996) developed at The University of Pittsburgh and the Knowledge Integration Environment (KIE) (1996) developed at The University of California-Berkeley. These tools typically allow a student to conduct research on the Internet or in the library, and develop schematic diagrams and models of the problem state. These models can be used to think critically and evaluate the premises one has developed to argue for or take up a certain position.

Providing Models

Scaffolding requires that instructors know about strategies and techniques used in specific settings which can be applied to tasks and used to solve problems. Instructors, then, are able to cue and prompt students in the appropriate use of helpful methods and approaches as they struggle to learn confusing material at the high end of their zone of proximal development.

A set of reflective judgment problems were used to help evaluate the short-term effectiveness of the engineering course under evaluation. Reflective judgment refers to one's cognitive ability to analyze a problem from many perspectives and reach a conclusion that can be justified with evidence gathered (Bruning et al., 1995). While faculty at this school were trained in the reflective judgment process and received information on how to assess students across seven developmental levels of reflective judgment, the engineering students never saw or studied this model directly. Rather, faculty attempted to incorporate its ideals into the course by periodically making statements such as, "there are no wrong answers, but you need to be able to defend your decisions."

Students showed statistically significant gains in reflective judgment by the end of the course (Reeves, 1996), so the faculty were not unsuccessful in their efforts. Still, too many students were making reference to the course as confusing and vague toward its end. In fact, faculty even suggested students were not using appropriate strategies to construct solutions throughout the course. It is suggested, then, that the engineering students could have benefited from a direct presentation of reflective judgment (see King and Kitchener, 1994) and problem-solving models (see Bruning et al., 1995), for as Pressley et al. (1992, p. 10) point out, the appropriate use of strategies in the classroom involves "students and teachers collaborating to work out an understanding of the strategies and how to use them effectively, rather than the teacher providing canned, standardized input."

Students should be shown up-front that problem-solving by nature is confusing and vague. This direct presentation would give them more confidence to try out a variety of solution paths without feeling like they were wandering haphazardly through meaningless trials and testing.

Establishing Standards

A variety of teaching styles were incorporated in engineering to deliver content to students. Students expressed mixed reactions to the styles with some preferring a traditional delivery of instruction and some preferring a dialectical, negotiated approach. One explanation for the variation in styles is simply instructor preference and tradition--delivering or negotiating content as they've always taught. Another explanation is that instructors were told to facilitate a new course that promoted intellectual curiosity in students, taught them how to frame and resolve ill-defined problems, and how to communicate effectively, yet no one gave the instructors important guidelines on how to facilitate and structure such a classroom.

One solution to the differences in teaching styles is to establish scaffolding standards which will ensure instructors have some knowledge of the process and will provide them with a reference point on which to base their performance. A number of models could be used to provide instructors with these standards, including six characteristics of scaffolding arranged by Rogoff (1990, p. 94): "1) recruit interest in the task; 2) simplify the task, reduce number of steps required; 3) maintain student interest and motivation on task, ensure persistence; 4) give feedback, pointing out differences in student performance versus ideal solutions; 5) control student frustration and risk in problem solving; 6) demonstrate the ideal version of performance.

Implications and Roadblocks to Solutions

Ensuring Self-Efficacy

The implications of inappropriate scaffolding are startling. Consider an engineering student without the prerequisite math skills to frame and resolve an ill-defined engineering problem. This student is faced with an instructor who refuses to scaffold based on the premise that all students in the institution are intelligent and capable of working hard to understand complex material. Provided this student continues to work hard but fails on task because he or she lacks necessary knowledge, what are the implications?

Self efficacy is a motivational construct stemming from the confidence learners feel in approaching and handling new tasks. According to Bandura (1993), self efficacy can be significantly lowered when students are told by instructors they have the skills to succeed on a task, they continue to try hard, yet fail. In these instances, students begin to attribute their failures to their innate abilities and might make statements such as, "I've always been poor at math, and there is no way I'll ever succeed in this course." In fact, older students tend to view their ability level as relatively stable and unchanging (Dweck & Leggett, 1988), so this potential outcome is magnified in educational settings beyond middle school.

This pattern of student attributions can subsequently effect student goals taken toward courses (Dweck & Leggett, 1988) as well as their motivation and curiosity (Weiner, 1994). Students who feel they lack the ability to succeed tend to undertake a performance orientation toward courses with a goal of failure avoidance. These students are typically motivated extrinsically and engage the course as a "means to an end" (Pintrich & Schunk, 1996, p. 258). Intellectual curiosity suffers as students fail to seek out external classroom resources and have little interest in elaborating on classroom content. Conversely, students having problems in the course who attribute them to lack of effort are more likely to undertake a mastery orientation toward the course and adopt goals of improvement and learning. These students are more likely to be intrinsically motivated and work hard to learn.

By employing EPSS technology or other technology scaffolds, it is possible to provide all students with support to keep their learning in a zone of proximal development. When challenge levels approach the high end of a student's zone, the learner may attribute troubles and failures internally if he or she doesn't have scaffolded supports. In such cases, the instructor should not proclaim that every student has the ability to succeed and leave them without support. Rather, the instructor should realize students have varying degrees of knowledge and provide each of them with the tools to obtain prerequisite skills. With proper support, students have no excuse for failure other than their own efforts. Getting a students to attribute their successes and failures to effort can lead to increased responsibility and performance on task (Weiner, 1994).

One potential roadblock to using an EPSS in the support of scaffolding is the mechanistic impression of technology. A key function of social constructivism and scaffolding is the nature of learning as a shared experience between the student, instructor, and their environment. Surely some will argue that the mechanistic computer can't be utilized in such environments. But, it is argued here that the nature of computing has indeed changed enough in recent years to begin incorporating computers as cognitive tools, to aid in scaffolding, and to promote situated learning environments. This is especially true of environments such as the Knowledge Integration Environment (KIE) (1996) that make explicit use of collaboration tools to engage students in discussion and debate about their ideas (e.g., threaded bulletin board discussion lists).

Other roadblocks worthy of mentioning include the significant time and monetary investment required to build an EPSS or to develop materials for a scaffolded support structure such as KIE. Further, unless the institution has a supportive organizational structure with open access to computers and the internet for their students, these types of interventions are inappropriate.

"Zones" and Inherent Vagueness

It is common for instructors to set up situations that are not easily handled by students and lie at the high end of their zone of ability. It is important for instructors to realize, however, that students must be keenly aware of strategies they can use to reach proximal goals, or the learning environment may simply be deemed "confusing" and "vague" as it was at this school.

In the case of this engineering course, students did not seem to be aware of problem solving methods and subsequently expressed feelings of confusion as they struggled with a multi-faceted, situated problem. Instructors often mentioned steps which could be useful in framing the "Mission to Mars" scenario, but they never provided direct instruction on specific models and steps that altogether would make the process of critically analyzing a complex situation seem more tangible. Further, in consideration of the first problem addressed and students' lack of prerequisite skills for this engineering course, Bruning et al. (1995, p. 102) point out "that metacognitive awareness compensates for low ability and insufficient knowledge. Developing metacognitive skills should be particularly helpful for students attempting to learn unfamiliar content."

Roadblocks to the inclusion of strategy instruction in situated environments include the time and effort required to teach them. Time is rarely scheduled into courses for teaching metacognitive strategies and how to self-regulate one's learning. Further, these are skills which are typically picked up individually through many years of schooling. Will scaffolding and cueing strategies in one classroom be immediately effective or will students only be capable of incremental changes? Bruning et al. (1995, p. 42) suggest that automatic processes "are acquired only through extended practice." Despite these roadblocks, instructors should not be afraid to employ scaffolding in their classrooms with collaborative activity and strategy instruction. According to Ford's (1992) Incremental versus Transformational Change Principle, change is not likely to occur dramatically, but rather, in small, evolutionary steps--a view shared by social constructivists who see change in learning as analogous to history: involving negotiation, time, and interactions with the external environment.

Promoting "Buy-In"

A positive implication of establishing scaffolding standards is providing for a common approach to negotiated instruction across several different instructors and ensuring both faculty and students are aware of roles they are expected to play in the dialectical approach. When students come to expect a negotiated approach to instruction where active participation is required, they will be less likely to complain about one instructor's style over another and less likely to blame difficulties they may encounter on these styles.

One potential roadblock to and a negative outcome of scaffolding standards is the inflexibility they allow different instructors in the teaching process. It is unhealthy practice to force instructors into a style of teaching with which they have no practice and no desire to implement. Further, despite the premise of this paper that certain problems in this engineering course could be overcome with scaffolding, it is quite possible that the dialectical approach is not always best for every situation. The content being taught during this engineering course was often technical and required that students have a familiarity with concrete formulas and hard fact that could subsequently be applied to a situated environment. The question is raised, then, can the meaning of a mathematical formula with a definite right/wrong application be socially negotiated? Perhaps this type of content is best "delivered" up front, as it was in this engineering course, followed by group work, classroom dialogue, and other activities to help integrate it into a real-world context.

Conclusions

The scaffolding technique can be used effectively in situated learning environments to support student acquisition of knowledge. Three problems with the use of scaffolding were identified at this school, including: a disregard of its value by some at the expense of students lacking prerequisite skills; student confusion related to inherently vague concepts like "reflective judgment" and confusing problem solving tasks; and, finally, differing approaches to scaffolding taken by several different instructors in the same course. Suggestions for solving these problems were offered, including: the incorporation of technology scaffolds into the course; direct instruction on reflective judgment and problem solving strategies rather than the repetitive mentioning of catch words such as, "you need to frame and resolve ill-defined problems"; and, finally, a need instructors to be exposed to standards of scaffolding as a point of reference on which to base performance.

Finally, it may be inappropriate to regard scaffolding as a purely social constructivist approach. With procedures ranging from teacher modeling to group work and classroom interaction toward the end goal of an independent learner, scaffolding lies on a continuum with its heart in socially negotiated settings but with its ends approaching more exogenous and endogenous points of view (see Figure 1). This detail suggests all three world views (Pepper, 1942; Prawat & Floden, 1994) are valid at different points in the instructional process and some may be more valid than others depending the need for delivery of hard content and facts versus the integration of this type of knowledge into real-world contexts.

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Philosophical Perspectives on How One Should Learn, Assumptions, and Methods

Exogenous, Mechanistic View, Mechanical Constructivism	*Dialectical, Contextualistic View, Social Constructivism*	*Endogenous, Organismic View, Radical Constructivism*
three perspectives lie on a continuum:		
◄ delivered instruction	negotiated instruction	personal instruction ►
• learner as "machine" • knowledge can be hierarchically structured with parts logically separated from wholes • learning from the environment and assimilation of information	• learner as "historical event" • knowledge is learned best when socially structured • learning from interactions with peers, teachers, society, who help one to assimilate and accomodate new information often through situated, real-world contexts	• learner as developmental "organism" • knowledge is learned best when individually structured • learning from oneself and the use of prior knowledge to reflect on and accomodate new information
Information Processing and Systems Theory Lecture Dependent Learning	Situated Cognition Goal-Based Scenarios Anchored Instruction Cognitive Apprencticeships – modeling Collaborative Learning – reciprocal teaching Zones of Proximal Development – scaffolding/fading hints, prompts, and cues	Self-initiated Research Activity Independent Study
dialectical scaffolding also lies on a continuum:		
◄ teacher modeling	give and take	general cues given ►

constructed from Beed, Hawkins, and Roller (1991), Choi & Hannafin (1995), Moshman (1982), and Prawat and Floden (1994)

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