Journal of Computing in Higher Education
Fall 2000, Vol. 12(1), 3-30.

Technology and Student-Centered Learning in Higher Education: Issues and Practices

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ABSTRACT

UNLIKE DIDACTIC APPROACHES that dominated both lecture and mediated instruction in the past, systems are emerging that are designed to extend the unique inquiry priorities and needs of learners. Student-centered learning environments (SCLEs) provide complimentary activities that enable individuals to address unique learning interests and needs. They invite learner engagement through relevant problem contexts and the availability of appropriate resources. Technology enables methods through which important thinking processes can be guided. They support inquiry through information seeking, retrieval, and generation. While significant advances have been reported, problems have also surfaced. This paper introduces student-centered learning, provides examples of exemplary post-secondary student-centered learning practices, and identifies problems and issues associated with adopting, adapting, scaling, and advancing student-centered learning in higher education. (*Keywords: student-centered learning, computer-based learning, problem-based learning)*

TECHNOLOGY AND STUDENT-CENTERED LEARNING IN HIGHER EDUCATION

INTEREST IN SUPPORTING learner-oriented teaching and learning models has grown dramatically during the past decade. Perhaps no single factor has influenced the growth of interest in student-centered learning as the emergence of powerful, user-friendly computer tools and the concurrent growth of the Internet and World Wide Web (Fetterman, 1998; Owston, 1997; Shotsberger, 1996). Interest in student-centered learning environments (SCLEs) that feature manipulation tools and distributed digital resources, has grown simultaneously. SCLEs support self-directed inquiry as well as information seeking, retrieval, and generation (Land & Hannafin, 1996). Unlike previously, where the development of computer-based materials was undertaken by those with the time, interest, and flexibility, virtually anyone can now generate their own multimedia resources and link them to resources developed by others.

This has engendered a movement from a highly centralized to a highly distributed model of education. Traditional college and university courses can still be taught largely as they were in the past, but we may no longer rely on them exclusively, or even principally, to provide degrees, courses, units, or even lectures. Individuals as well as groups can initiate and pursue learning needs of their individual choosing, selecting resources they deem to be appropriate and relevant, adapting existing or contributing new resources, and otherwise determining what to learn, how to learn, and when learning needs have been satisfied.

Yet, technology developments are characterized more by increases in activity than rigorous discipline in the inquiry. Despite advances in technology, a significant impact has yet to be realized. Teaching-learning approaches have often been reused, not redefined. Technology is largely accomplishing what was done previously without technology; few have unleashed its potential.

SCLEs represent significant potential for optimizing the capabilities of both technology and learners. While the potential is indisputable to some, several problems and perils have already surfaced. Some have questioned if learning occurs, how such systems should be designed, and the generalizability of such approaches across domains and tasks (Dick, 1991; Merrill, 1991). The feasibility of implementing student-centered approaches within traditional classroom environments has also been questioned (Salomon, 1997). The purposes of this paper are to provide a brief summary of student-centered learning, describe examples of exemplary student-centered learning practices, and identify several practical problems and issues associated with adopting, adapting, scaling, and advancing student-centered learning in post-secondary education.

STUDENT-CENTERED LEARNING ENVIRONMENTS: A PRIMER

SCLEs EVOLVED as a result of shifting beliefs and assumptions about the role of the individual in learning (Hannafin, Hill, & Land, 1997). They provide "...interactive, complimentary activities that enable individuals to address unique learning interests and needs, study multiple levels of complexity, and deepen understanding" (Hannafin & Land, 1997, p. 168). They "...promote engagement through student-centered [learning] activities" (Hannafin, 1992, p. 51). They often use technology to enable flexible methods through which important cognitive processes can be scaffolded to both augment and extend thinking and learning (Land & Hannafin, 2000).

During the past decade, perspectives on the role of technology have broadened both conceptually and operationally (Hooper & Hannafin, 1991). This is reflected in the nature and breadth of experiences made available and in the capacity to support them electronically. Sophisticated learning environments, representing evolving notions of the partnerships among learners, experience, discourse, and knowledge, have been developed. For instance, computers and "probeware" allow learners to measure real-time changes in temperature, oscillatory motion, or light intensity, helping them to visualize and speculate about normally "invisible" processes (Kelly & Crawford, 1996; Lewis, Stern, & Linn, 1993). Similarly, learners can explore the effects of objects in gravity-free contexts, simulate probability experiments over thousands of trials, or download real-time meterological data and population statistics for analyses. Mainstream computer conferencing tool such as *WebCT.com* or *Blackboard.com* enable discourse by all members of a classroom, without the constraints of class size, time, and place. With SCLEs, technology extends how concepts are represented and how learners can be supported to generate and think about them (Pea, 1985).

SCLE FOUNDATIONS

All learning environments are rooted in core foundations: Psychological, pedagogical, technological, cultural, and pragmatic. While each foundation can be understood separately (see Hannafin & Land, 1997, for detailed accounts of each foundation), in practice they function interactively. In the following section, we provide a brief example of the interplay among foundations.

The interplay between psychological and pedagogical foundations is perhaps the easiest to understand. Psychological foundations address how individuals learn, that is, acquire, organize, and deploy knowledge and skill. Pedagogical influences focus on the activities, methods, and structures of the learning environment, that is, how it is designed and how its affordances are made available. Psychological foundations account for how learning occurs, while pedagogical foundations dictate the methods and activities associated with varied design models (see, for example, Hannafin & Rieber, 1989). Different psychological foundations dictate different teaching and design strategies. For instance, instruction based on behaviorist psychological principles will utilize very different approaches and strategies from instruction based on principles of situated cognition. This is a basis for grounded design practice: The strategies employed in a given learning system can be linked to corresponding psychological roots reflecting assumptions about how individuals learn (Hannafin, Hannafin, Land, & Oliver, 1997). Different underlying assumptions *should* yield different approaches.

SCLEs typically reflect two related psychological foundations: Social cognition and constructivism. (Note that while many suggest that constructivism is more a philosophical/epistemological perspective than a psychological theory, we use it here to define a perspective on how one comes to know and understand.) Both approaches view the learner as an active constructor of meaning rather than a passive observer or recipient of information. Social cognitivists emphasize the socially-mediated aspects of learning as well as the influence of social context of understanding (Greeno, 1997). Constructivist foundations reflect situated views of cognition, that is, that knowledge and context are inextricably tied (Brown, Collins, & Duguid, 1988). Knowledge isolated from a meaningful context is of little productive value and will likely remain "inert"; learners cannot apply what they learned (Bransford, Franks, Vye, & Sherwood, 1989). The emphasis on learning environments that provide contextually-rich, authentic experience is a direct outgrowth of these perspectives.

Constructivists view learning as being influenced by both situational factors and the unique sense-making of the individual. Knowledge—especially deep, personalized knowledge versus compliant knowledge—is individually constructed. Understanding is both defined by and derived through experience, not simply by "telling" (Bransford, et al., 1989). The goal is to provide activities, tools, and resources through which the individual comes to know and understand through experience. SCLEs afford concrete experiences that catalyze the constructing of individual meaning. These are typically provided in the form of problems to be addressed, cases to be analyzed, or "open" problems determined uniquely by the individual (see Hannafin, Land, & Oliver, 1999).

Technological foundations can be viewed as providing enabling capabilities. Taken independently, these capabilities establish what is *possible*, not necessarily what is required or desired. Considered together with psychological and pedagogical foundations, technological foundations represent how the capabilities and limitations of available technologies can be optimized. In support of student-centered learning, for example, computer tools often assist in locating, collecting, and manipulating resources (e.g., search engines or search indices). On-line scaffolding can be provided to assist learners in planning or implementing their learning or to "coach" the reflective processes underlying an activity. For example, Salomon, Globerson, and Guterman (1989) embedded scaffolds into the software, "The Reading Partner," to prompt learners to reflect on their understanding while reading. Similarly, Lajoie (1993) studied an avionics troubleshooting environment that tracks learner actions and periodically summarizes them in order to facilitate reflection and evaluation of prior strategies. Communication tools such as discussion boards might permit collaboration among learners engaged in similar investigations. Generative tools, such as Web editors, may be used to develop hypermedia artifacts of learner understanding. The key, of course, is the alignment of technology affordances with the underlying psychological and pedagogical foundations.

Cultural and pragmatic foundations are also aligned with the basic tenets of student-centered learning. Cultural foundations reflect prevailing beliefs about education, the values of a community, and the roles of individuals in society. Cultural foundations influence the design of learning systems by reflecting social mores and values concerning the nature and role of education. All learning environments reflect, in a very real sense, the philosophy of a parent organization (e.g., Regents, school boards). U.S. education has been dominated by a "factory" or industrial model of education (Reigeluth & Squire, 1998). The goal was largely to educate the masses, with corresponding approaches that established grade levels, curriculum structures, teaching activities, and vacation schedules. Contemporary education culture has evolved to support philosophical shifts in the nature of teaching, learning, and technology; economic imperatives and the desire to contain the costs of post-secondary education have likewise emerged. SCLEs provide a means to meet the knowledge requirements of a rapidly expanding technological society and other emerging cultural needs.

Finally, pragmatic foundations bridge the gap between theory and reality. In a very real sense, they determine what *can be* in a learning environment. Pragmatic influences include hardware, software, and bandwidth limitations as well as faculty-student ratios. They balance human and technological assets and limitations as well as situational factors.

Learning environments become increasingly distinctive as their core psychological foundations differ (e.g., behaviorism vs. situated cognition), and increasingly similar as the psychological foundations are alike (social cognition vs. situated cognition). SCLEs, therefore, differ from traditional didactic instruction in that they support learning using fundamentally different teaching approaches. SCLE's psychological framework is consistent with constructivist-situated cognition perspectives, emphasizing powerful, authentic learning contexts and student-centeredness. SCLE activities include contextually-referenced problem statements and framing rather than explicit behavioral objectives and isolated instructional content, varied resources reflecting multiple perspectives rather than a singular "correct" perspective, and angling and scaffolding rather than the most "efficient" didactic approach.

STUDENT-CENTERED LEARNING ENVIRONMENTS IN POST-SECONDARY SETTINGS

DIVERSE EXAMPLES OF STUDENT-CENTERED LEARNING in higher education have emerged over the past decade. Some of the more commonly practiced approaches include problem-based learning (Savery & Duffy, 1996), case-based reasoning (Kolodner & Guzdial, 2000), computer simulations (de Jong & van Joolingen, 1998), design projects (Perkins, 1986), and computer-supported collaborative learning (Koschmann, 1996). In this section, we describe two of these approaches—problem-based learning and design projects. For each approach, we provide an overview of its components and theoretical foundations and give a brief description of examples that illustrate major purposes, features, and methods.

PROBLEM-BASED LEARNING

Problem-based learning (PBL) is probably most widely implemented in professional education—in law and medical schools in particular—but it has also been used as a framework for teaching in engineering, teacher education, science, and business (Koschmann, Kelson, Feltovich, & Barrows, 1996). Rather than isolate discipline knowledge from clinical experiences (e.g., biomedical science from authentic medical practice), PBL anchors the learning process in real-world or simulated cases. Typically, small groups of learners will study the cases, and together with a facilitator, analyze the case events, generate interpretations, and form tentative conclusions. In some instances, such as diagnosing a patient disease, a "correct" solution to a problem may be expected. In others, learners debate a "best" solution—one of many that are possible—based on constraints, facts, or case histories outlined in the problem (e.g., an engineer determining how to design a bridge to sustain an earthquake). With PBL, simply generating a "solution" to a problem is insufficient. Learners must defend their analyses and justify their responses, using facts and theories of a discipline to support their conclusions.

PBL has emerged in response to transfer problems related to the separation of knowledge and its application and the desire for more authentic teaching-learning practices. Traditionally, learners are taught the working knowledge and skills of a discipline independently from how they are integrated into everyday practice. This approach often results in inert knowledge that cannot be *used* effectively in situations where it is needed (Bransford et al., 1989). Instead, learners may fail to recall what they learned, often over-simplifying their understanding of a complex domain (Spiro et al., 1991) or failing to reason with and apply knowledge to address new problems (Perkins & Simmons, 1988).

PBL supports learning in a manner consistent with the reasoning processes used by practitioners. Learners generate hypotheses or theories, gather data, and form and evaluate conclusions. Through an iterative process of "learning by doing," they consider problems, consult resources and reference texts, and identify gaps that require further study or a refining of initial theories. A trained facilitator (or instructor) guides the reasoning process, modeling and externalizing these strategies to learners at pivotal points in the learning process.

SCLE mediated cases in medical education. PBL applications have become almost commonplace in medical education (Aspy, Aspy, & Quimby, 1993). An early application of technology-mediated PBL in medical education is the *Case of Frank Hall* (Harless, 1986). This program is a PBL simulation that engages learners in emergency intake interviews, forming an initial diagnosis, formulating and implementing an initial battery of exams, and following the initial process through a determination to admit, treat, or release. The learner needs to interpret and analyze initial case data, evaluate possible alternative diagnoses and treatment plans, and follow the patient status in terms of both health condition and cost implications of the treatment.

Similarly, Hmelo and Day (1999) describe a multimedia PBL case designed to "anchor" the learning of cancer biology. The case simulates a woman's plight with breast cancer. She is treated initially but later discovers that the disease has spread to her bones. Learners use computer tools to conduct a simulated interview with the patient, physically examine her, and order laboratory tests. They use a multimedia database to retrieve patient files and X-ray images as well as view a breast biopsy. While working through the case, embedded questions prompt learners to generate hypotheses and to refine them as they confront additional pieces of evidence (e.g., after viewing a breast biopsy, explain why the growth pattern changed).

Throughout the case, learners consider questions and issues designed to prepare them for subsequent group discussions about the case. For instance, they are asked to prepare case summaries of their observations and inferences, to reflect on causal mechanisms, to interpret the significance of specific test results, and to explain why a specific event occurred. Considering these questions in advance helps to focus classroom discussions and improve awareness of different perspectives on the issues involved. The problem-based simulations provided a mechanism for learners to explore a knowledge base in its complexity and to discuss multiple ways of handling a problem. Yet, by anchoring biological concepts in a case, learners are assisted to focus on, and reason about, core clinical issues.

DESIGN PROJECTS

Project-based approaches encourage learning through student-directed investigation, often in the form of design projects (Baumgartner & Reiser, 1997; Blumenfeld et al., 1991; Resnick, 1998). Design projects typically feature the following student-centered activities:

a) learners propose questions, problems, or designs for investigation;
b) learners produce tangible products, or "artifacts," that represent their constructed knowledge; and
c) learners make available their project artifacts for public review (Blumenfeld et al., 1991; Resnick, 1998). Through public posting and discussion of project artifacts, learners engage in social interactions designed to deepen understanding (Laffey, et al., 1998).

Design projects reflect *constructionist* values and beliefs. Learners "literally build or construct understanding by creating artifacts (papers, documents, speeches, journals, etc.)" (Nicaise & Crane, 1999, p. 30). Through the process of building artifacts indicative of their understanding, learners create personally meaningful representations of the domain of study.

At Penn State, for instance, preservice teachers enrolled in a science course for non-majors engage a series of projects from the perspective of an engineer (Taylor, Lunetta, Dana, & Tasar, 1999; see also http://www.ed.psu.edu/ci/scied/scied497f/). In order to understand concepts of force, tension, compression, equilibrium, and vector components, learners construct simple truss models using string and Lego™ pieces. They are placed in the role of engineers tasked to construct a scale model of a truss bridge that will span a local river. Utilizing software such as *West Point Bridge Designer*, as well as physical models constructed in the classroom, learners design, simulate, and test their structures. The design project serves as a powerful context to access and apply physical science concepts in ways typically reserved for advanced science or engineering majors and practicing engineers. Learner-generated design projects provide an opportunity for reflection, as learners apply what they learn to justify and progressively improve both their designs and understanding (Resnick, 1998).

Design projects in teacher education. Professional development efforts, such as inservice teacher education, may benefit from design projects to help individuals apply new ideas to existing practice. For instance, Soloway, Krajcik, Blumenfeld, and Marx (1996) developed a computer-based tool (*Project Support Environment*) to help teachers plan, learn, and develop project-based science strategies in their classrooms. The *Project Support Environment* includes tools to support the management of various phases of project development such as formalizing concept maps of initial ideas, calendars for planning timelines, and libraries of existing projects that can be modified. The environment also includes design templates to help teachers construct and modify project designs and to articulate why various strategies are important to project-based science. Finally, to enhance reflection, tools are provided to facilitate the comparing and sharing of project artifacts. Through multimedia case libraries, teachers are exposed to authentic and effective project-based science cases. The cases highlight important features of project-based science as well as challenges faced by teachers during implementation. In addition, through use of telecommunications, teachers post their own lesson designs to the Web for public review and discussion. Engaging in conversations about project artifacts serves both teaching (as peers learn from other peers) and evaluative functions (as new ideas are considered in light of others' designs for similar tasks and problems).

PROBLEMS AND ISSUES

DESPITE THEIR THEORETICAL PROMISE, learners frequently do not use SCLEs as presumed (Salomon, 1986). Simply providing rich opportunities for learning does not guarantee that learners will seize them (Perkins, 1985); it is necessary but insufficient. SCLE's open-ended nature requires thinking-intensive interactions that may cause difficulty for novice learners. For instance, learners must generate, test, and revise hypotheses, use metacognitive and self-regulation strategies, select relevant from irrelevant information, and monitor the success of varied strategies (Salomon, 1986). Instructors must diagnose if learning is progressing and provide needed guidance—tasks often complicated by thinking processes that are tacit and otherwise difficult to "see."

In practice, SCLEs' potential is influenced by several implementation factors, including cognitive demands on learners, need for individualized guidance by instructors, institutional constraints of 16-week class sessions, established curriculum, and traditional grading requirements. The following section outlines several problems and issues that influence SCLE implementation in higher education.

THE SITUATED KNOWLEDGE PARADOX: "I KNOW WHAT I KNOW"

SCLEs help learners to ground their interpretations in everyday experience (Land & Hannafin, 2000). By using realistic contexts and complexity (e.g., understand engineering by solving real-world engineering problems), learners observe how and why knowledge is useful while studying authentic problems (Cognition & Technology Group at Vanderbilt, 1992; Spiro et al., 1991). While lacking specific to-be-learned domain knowledge, learners likely have *some* related experiences or ideas that can be built upon as an initial foundation. In complex SCLEs, learners build progressively upon this incomplete foundation by connecting new concepts to those already known (Brown, Bransford, Ferrara, & Campione, 1983).

For instance, learners might enter an introductory physics course with little formal knowledge related to optics and light. However, if asked what they already know about light, they might generate a number of initial ideas that are plausible and rooted in everyday experience (e.g., it is brighter at its source; it is reflective; it emits energy). Connecting to-be-learned with prior knowledge or experience is believed to enhance transfer and promote meaningful, long-lasting understanding (Brown et al., 1989).

Sometimes, however, naïve conceptions or working theories are incompatible with, or contradictory to, formal, accepted explanations (Carey, 1986). Novices organize knowledge differently from experts, since they lack foundation domain knowledge that is coordinated into patterns in memory; this, in turn, affects both how problems are represented and how new knowledge is integrated (Chi, Feltovich, & Glaser, 1981; deGroot, 1965). When learners draw upon unstable or inaccurate prior knowledge to organize new knowledge, they may paradoxically strengthen sophisticated *misunderstandings* that are both robust and difficult to alter (Land & Hannafin, 1997).

In one of our prior research studies, we found that learners (7th graders) often made references to prior beliefs and experiences about force and motion that interfered with new learning (Land & Hannafin, 1997). Learners held strong, intuitive beliefs about how objects speed up and slow down, based largely on their everyday experiences (e.g., objects slow down when brakes are applied and speed up when an engine provides horsepower). Rather than using these beliefs and experiences as a basis for developing scientifically-valid explanations, learners became entrenched in them and failed to evolve them significantly. Persistent confirmation bias (Chinn & Brewer, 1993) was evident, where preconceptions are used to selectively perceive information that supports a theory, while contradictory evidence is ignored. Prior knowledge and everyday experience apparently supports learner beliefs, strengthening the persistence of naïve theories. These observations are often unreliable and unpredictable and cannot easily be *disconfirmed*, given the nature of observations and limitations in the features of the SCLE. Similar findings have been replicated for scientific and mathematics learning from elementary through college age learners (de Jong & van Joolingen, 1998).

These problems pose a conundrum—a situated knowledge paradox— that involves how learners build upon prior conceptions when they are faulty or incomplete. SCLEs create contexts for learning that are consistent with authentic practice while recognizing the importance of building upon learner initial, naïve conceptions. Yet, learners who lack refined knowledge may misapply prior experiences or perceive inaccurately information to confirm their naïve theories (Brickhouse, 1994; Chinn & Brewer, 1993). They also may experience difficulty discerning relevant from irrelevant information, making imprecise observations that are not easily detected or reconciled (Roth, 1995). Alternatively, relying upon traditional classroom contexts that constrain and simplify may reduce the likelihood of interference from learner faulty theories, but promote oversimplified understanding of limited transfer to more complex contexts (Brickhouse, 1994; Spiro et al., 1991).

THE METACOGNITION PARADOX: "I DON'T KNOW WHAT I NEED TO KNOW"

Learning in resource-rich environments requires metacognitive knowledge to monitor what is already known, what needs to be known, and how to find what is needed (Moore, 1995). With information technologies, metacognitive knowledge is essential to identify information needs, generate search terms, separate relevant from irrelevant information, and to monitor strategies (Hill & Hannafin, 1997; Moore, 1995). Additionally, learners must monitor their investigation, remaining focused on the "forest" without getting lost in the "trees" (Chang & McDaniel, 1995). Finally, learners must integrate information coherently, drawing upon information and perspectives from a variety of sources (Land & Greene, 2000).

Effective monitoring requires ongoing awareness of understanding in order to mediate the fit between "local" information and global understanding (Land & Greene, 2000). The process requires that learners "spontaneously mobilize prior knowledge to generate questions on a little-known subject" (Moore, 1995, p. 10) and to refine questions in light of new information. Yet, reflecting on what is known and what needs to be known requires knowledge of the domain (Garner & Alexander, 1989; Greene, 1995) and is unlikely to occur without external scaffolding, support, and modeling (Scardamalia, et al., 1989).

SCLE research in higher education settings suggests a complex relationship between domain knowledge and metacognitive knowledge (Hill & Hannafin, 1997). With limited domain knowledge, it is difficult for learners to deploy metacognitive strategies to identify appropriate search terms, determine what is relevant, and generate driving questions for investigation (Soloway et al., 1996). Learners who lack adequate prior domain knowledge tend to generate broad or vague search terms, fail to refine ineffective strategies, abandon initial lines of inquiry, and reveal persistent fragmentation of understanding (Land & Greene, 2000). This is further complicated since covert, metacognitive processes are difficult for both learners and instructors to identify, and thus evaluate. When topic knowledge is incomplete, problems in the strategic use and evaluation of information resources are likely. Hence, it is increasingly important to generate support mechanisms to help learners monitor and refine their inquiries and to make metacognitive processes more "visible" (see for example, Lin et al., 1999; Scardamalia et al., 1989; Schwartz et al., 1999) to instructors and learners.

LEARNING BY DOING: "DO I HAVE TO EXPLAIN WHAT I DO?"

Learning with SCLEs often entails developing artifacts that pull together ideas and represent understanding. Examples of student-constructed artifacts include multimedia presentations, electronic portfolios, physical scale models (e.g., scale model of a bridge), design documents, and hypermedia "chapters" (Nicaise & Crane, 1999; Resnick, 1998). The constructing of artifacts is presumed to be a motivating activity that supports unique learning goals in personally meaningful ways to represent understanding.

However, researchers have identified problems related to learning-by-doing in both K-12 and post-secondary contexts, where the creating of artifacts dominates the process of reflection presumed to underlie the artifacts. For instance, Baumgartner and Reiser (1997) noted: "Design projects inherently value the performance of the designed artifacts, and may bias students to focus on optimizing their design rather than investigating what affects the performance of their design ... Students who do focus on inquiry need guidance to be able to ... thoughtfully reflect on their design and why it worked as it did." (pp. 2-3).

Other researchers have suggested problems related to the time spent creating artifacts versus thinking deeply about the underlying processes; conceptual understanding often suffers. For instance, Nicaise and Crane (1999), found that artifacts (in this case, hypermedia chapters) developed by graduate students reflected superficial, and often misconceived, understanding of the course concepts. They noted that, "...many of the actual products (chapters) were modest at best... Also, although all students cited relevant literature in an attempt to provide supporting evidence for claims made in the chapter, fewer than half were able to explain the research and integrate it meaningfully. Instead, chapters became opinion pieces devoid of supporting evidence" (p. 39).

One explanation for their findings was that learners were required to accomplish "too much in too little time" (p. 43). They were given 16-weeks to learn both the subject matter and the technical skills required to construct a Web-based, hypermedia chapter. They reportedly spent roughly 50% of their time learning new technologies. Although student-constructed artifacts may be more meaningful, attention must also be dedicated to helping learners articulate, reflect upon, and revise their understanding of *why* their designs work and the rationale underlying their artifacts.

COMPLIANCE AND DEPENDENCE: "WILL THIS BE ON THE TEST?"

SCLEs provide contexts for learners to pursue unique learning goals and to decide which issues and information are relevant to their needs. Learners direct the learning process, evaluating new information in light of current theories, questions, or beliefs. Instructors elicit and clarify learner understanding, facilitate discourse around varied perspectives, diagnose limitations in thinking, introduce the tools of the trade, and stimulate alternative points of view (Petraglia, 1998).

This approach differs substantially from many traditional approaches where instructors decide what is important to learn, present the requisite information, and assess how well learners have met these standards. In traditional contexts, tacit and explicit expectations emerge as to teacher and learner responsibilities (Land & Hannafin, 2000). "Good" learners, for example, look to instructors or assignments for direction regarding what is important to study and the requirements of desired performance (e.g., how many pages are required, how many references should be included, etc.). "Good" teachers, in turn, define the steps and criteria for success and help students to focus on information that is most likely to address them.

Compliant approaches evolve and influence how (or if) learners or instructors accept and engage SCLE investigations. Instructor and learner orientations toward the investigations influence both their views of the task and their role in the learning process. Traditional practices tacitly reflect a belief that knowledge is supplied from an authority figure to a subordinate (Kitchener & King, 1981)—from expert to novice, or transmitter to receiver. SCLEs, in contrast, rely on the individual learner to establish goals and monitor their attainment. Learners schooled in traditional didactic approaches may find themselves frustrated as they attempt to identify non-existent externally-defined learning goals and match their responses with irrefutably correct answers; instructors may become frustrated as they observe students struggling or feel pressured by students to provide definitive answers and guidance.

SCLE research has shown that children tend to seek and rely heavily upon external regulation (e.g., general suggestions; guiding questions; requests for verification from teachers). Rather than reflect on learning tasks or available evidence to form strategies, they tend to adopt guidance as "required" goals, answers, or procedures; familiarity with traditional schooling practices, in effect, tends to breed dependence on them (Land & Hannafin, 1997; Oliver, 1999). Similar patterns have been reported with adult learners, suggesting potentially significant problems when epistemological orientations are inconsistent with the constructivist values embodied in SCLEs (Hill & Hannafin, 1997; Jungworth, 1987; Kuhn, 1999).

TRADITION AND THE ACADEMY: "WHOSE PERFORMANCE MATTERS?"

A fundamental question arises as to whose performance matters in post-secondary settings: Is the goal principally one of teaching or one of learning? If the goal is principally one of learning, then our existing approaches may be largely mismatched. Higher education institutions tend to emphasize course evaluations over student performance and accomplishments, what is taught over what is learned, and teaching classes rather than the individual. Teaching and learning approaches can be integral to one another, but the focus on teaching over learning has a long-standing tradition in higher education. Student-centered approaches, at their core, emphasize both what is learned and who learns, not necessarily whether specific information is learned or the scores of collections of students across common content.

These represent core shifts in teaching-learning values. At times, faculty conceptions of teaching and learning are inconsistent epistemologically or incompatible pedagogically with student-centered approaches (Jungworth, 1987). This is not altogether surprising. Most instructors have been reared in the tradition of the academy, emphasizing didactic approaches such as lecturing as the dominant method: They teach as they were taught. The archetype of the lecturing instructor—the "sage on the stage"—is familiar and comfortable for many professors. Post-secondary institutional cultures implicitly support such practices.

Yet, research spanning the past two decades provides compelling evidence that didactic instruction often fails to produce deep, durable understanding; instead, it can promote over-simplification, compliant thinking, and superficial understanding (McCaslin & Good, 1992; Perkins & Simmons, 1988; Spiro et al., 1991). Didactic approaches often fail to account for varied backgrounds and interests, typically placing the learner in largely passive, receiver roles rather than active, generative roles. Our traditional approaches may not support the kinds of learning we value, but we perpetuate them nonetheless.

Moving beyond didactic methods can be especially problematic for faculty with limited experience with or pedagogical knowledge of alternative methods. They require assistance at multiple levels before becoming sufficiently comfortable to implement approaches independently. Many report reluctance to rely on technology in their classrooms, citing a lack of support needed to develop and sustain their efforts (Green, 1999; Surry & Land, 2000). Even with adequate background knowledge, striking a balance between guiding and directing is challenging (e.g., When am I giving too much direction? When am I not giving enough? How do I distinguish a "teachable moment" from inefficient floundering?). In addition, assessment in grade-driven systems is problematic, particularly with large class sizes and other constraints on faculty time.

SCLEs require flexibility and comfort with diverse learner-generated topics and phases of progress. Nicaise and Crane (1999) expressed the following experience as instructors of a student-centered, graduate level course:

> From an instructor's perspective, one of the greatest difficulties rested with managing several project topics because it was difficult to remember the intricate nuances associated with each student's separate project, provide students with multiple resources on wide-ranging topics, and discern at what level students understood their topics so that student learning could be scaffolded. (p. 44)

In instances where large numbers of learners and diverse topics are pursued, management and support of a student-centered classroom can be challenging. Identifying the frameworks and tools that support student-centered learning remains a promising, yet unmet, need (see for instance, Loh et al., 1997; Schwartz et al., 1999).

CONCLUSIONS

THE TRANSITION TO STUDENT-CENTERED LEARNING ENVIRONMENTS is inevitable; indeed, several significant efforts have been demonstrated or are already underway. While a great deal has been learned from available research and theory, it is naïve to presume that research and theory alone shaped SCLEs. Rather, SCLEs emerged as a natural consequence of widespread availability of powerful, ubiquitous technologies that support inquiry of all kinds in all places, not simply in formal schooling. Different models of inquiry have become possible through technology; the challenge is not so much to invent new teaching-learning models as to understand and optimize those models that have emerged.

It is tempting to position SCLEs and didactic approaches as polar opposites in a "winner take all" epistemological struggle: One position must be correct and prevail, while the other must be flawed and thus vanquished. It is tempting, but unreasonable. SCLE approaches will undoubtedly continue to emerge, but they do not portend the demise of didactic approaches. SCLEs open domains of study to the unique needs and sense-making of learners; they do not, however, explicitly clarify what is of general importance and significance. SCLEs and didactic approaches have important roles in the educational toolkit of instructors and students. We do not posit SCLEs, or any other approach, as the definitive "new best way"; we need, however, to determine when different tools make sense and how to utilize them.

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