Part 1

Overview

1 Student-Centered Learning Environments

Foundations, Assumptions and Design

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Student-centered learning environments (SCLEs) “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). This general framework is used in the learning sciences to delineate design methods that support personal sense making via problem contexts enriched with technology tools, resources, and scaffolding (Quintana, Shin, Norris, & Soloway, 2006). Such environments facilitate student- or self-directed learning by enabling students to productively engage complex, open-ended problems that are aligned authentically with the practices, culture, or processes of a domain.

During the past two decades, new frameworks for designing learning environments have emerged in response to constructivist-inspired views of learning (Jonassen, 1991). Such views represented a fundamental shift in the paradigms of learning and design during the 1990s, but few guidelines were available for designers to create learner-centered environments. Likewise, as technologies advanced, approaches evolved to integrate digital resources, tools, and connectivity to expand the designer’s toolkit. These shifts in the learning–design–technology landscape required corresponding shifts in theoretical and design frameworks to capture emerging viewpoints and technologies for learning (Hannafin & Land, 1997).

The National Research Council Report (Bransford et al., 2000), How People Learn, established principled-based approaches to designing learner-centered environments, emphasizing learning with understanding and the importance of social and cultural contexts in learning. These perspectives require very different approaches to design, teaching, and assessment, including the importance of learner preconceptions, deep, usable knowledge, and metacognition as processes that mediate individual learning. One implication for learning-environment design drawn by the NRC is that “schools and classrooms must be learner centered”

(Bransford et al., p. 23). The 2006 edition of the Cambridge Handbook of the Learning Sciences further expanded the 2000 NRC report, aligning Learning Sciences research and development with the goals of student-centered learning outlined in that earlier work (Sawyer, 2006).

Despite the 2000 report detailing the prevailing views on how people learn, debate about the veracity of assumptions about learner-centered designs has re-emerged, with questions arising about the research evidence available in support of constructivist approaches (see for example, Hirsch, 2001; Kirschner et al., 2006). Indeed, unlike for traditional instruction, no unifying theory seems to guide the design of student-centered learning environments, which creates challenges for research, scalability, and generalizability. We acknowledge the efficacy of varied approaches to teaching and design, with design decisions being a byproduct of different contexts, tasks, pragmatics, and goals. This chapter focuses on introducing the tenets of student-centered learning environments that are grounded in foundations, assumptions, and methods associated with constructivist epistemology.

Theoretical Background

The Role of Epistemology in Learning Environments

Epistemological shifts have engendered a variety of innovative and provocative learning environments. Interest in student-centered teaching and learning, for example, has given rise to myriad approaches to provide flexible and powerful alternatives to the design of instruction (Jonassen, 1991). Student-centered environments, tacitly or explicitly, are designed to support individual efforts to negotiate meaning while engaging in authentic activities. Student-centered approaches reflecting epistemological variants have emerged including problem-based learning (Hmelo-Silver, 2004), anchored instruction (Cognition and Technology Group at Vanderbilt, 1992), cognitive apprenticeships (Collins, 2006), computer-supported collaborative learning (Stahl et al., 2006), learning-by-design (Kolodner, 2006), project-based learning (Krajcik & Blumenfeld, 2006), games and simulations (D. Clark et al., 2009), and open learning environments (Hannafin, Land, & Oliver, 1999). While operationalized differently, student-centered learning environments share common epistemological foundations and assumptions. SCLEs are grounded in a constructivist view of learning, where meaning is personally rather than universally defined. Such perspectives draw heavily from psychological research and theory related to areas such as situated cognition (Brown, Collins & Duguid, 1989) with attendant assumptions emphasizing the interlacing of content, context and understanding, the individual negotiation of meaning, and the construction of knowledge (Jonassen, 1991). Pedagogically, SCLEs favor rich, authentic learning contexts over isolated, decontextualized knowledge and skill, student-centered, goal-directed inquiry over externally directed instruction, and supporting personal perspectives over canonical perspectives. Technology tools support the individual's identification and manipulation of resources and ideas (Iiyoshi, Hannafin, & Wang, 2005).

With increased popularity, however, fundamental questions have arisen related to the kinds of learning such environments support, how best to design them, and whether or not designs can be generalized across varied domains and contexts (Dick, 1991; Merrill, 1991; Kirschner et al., 2006). Numerous "how to" guidelines have been offered, but they typically lack adequate theoretical or empirical framing (Hannafin & Land, 1997). Given the unique student-centered learning goals and requirements, it may be impossible to derive an inclusive design model. Rather, we need to identify frameworks for analyzing, designing, and implementing learning environments that embody and align particular foundations, assumptions, and practices.

Clark (Clark & Hannafin, 2011) recently described "pitfalls" and shortcomings of constructivist-inspired learning environments such as discovery learning research and practice, citing examples to support his assertion that fully-guided, direct instruction results in superior performance in virtually all cases. Similar arguments have been presented for constructivist-inspired learning strategies and environments including student-centered learning, inquiry-based learning, and self-directed learning (Kirschner et al., 2006). Clark also suggested that empirical evidence generated from directed-learning studies is applicable to all types of learning independent of the associated epistemological roots. He suggests personal perspectives might unduly sustain the popularity of minimally-guided approaches in the absence of empirical evidence. Finally, Clark cautions "Far too many in our field are avoiding inconvenient evidence in favor of self-serving beliefs and opinions" (p. 375). He questions the preparation and motivation of non-adherents: "few people have the motivation or training necessary to invest the effort required to carefully review complex research on learning and instruction … ambivalence about research training in our instructional technology and instructional systems graduate programs is certainly a contributing factor" (p. 375). He concludes that programs that do not heed his advice "risk causing harm to people who depend on us" (p. 375).

But are the goals, assumptions, and learning contexts of these approaches really comparable to those based on learning from direct instruction? Clark et al.'s guidance is only occasionally viable when the circumstances and assumptions guiding design decisions are aligned. His perspectives, methods, and findings do not align with widely adopted approaches advanced by reputable theorists, researchers, and practitioners with different perspectives. Hmelo-Silver, Duncan, and Chinn (2007) challenged Kirschner et al.'s (2006) use of the term minimal guidance:

"problem-based learning (PBL) and inquiry learning (IL), are not minimally guided instructional approaches but rather provide extensive scaffolding and guidance to facilitate student learning" (p. 99). McCaslin and Good (1992) noted, "the intended modern school curriculum, which is designed to produce self-motivated, active learners, is seriously undermined by classroom management policies that encourage, if not demand, simple obedience" (p. 4). The authors suggest that both teachers and students require sustained opportunities and support in order to adapt and implement significant pedagogical changes. Optimal guidance is needed where learning outcomes are not or cannot be explicitly predefined.

We do not argue for inherent superiority (or inferiority) of one perspective or approach over alternatives. We do not intend to fuel what is often a rancorous ongoing debate, but to advance a more principled approach to linking teaching, learning, and technology. Since learning is the goal of design, we need to clarify the type(s) of learning we mean to facilitate. Learning systems design has evolved frameworks that provide important and useful ways to support directed learning. So, while we acknowledge that fully-guided direct instruction is often well-suited to support external learning requirements, these same methods and models cannot adequately support learning that has become increasingly spontaneous and self-directed within and across formal (e.g., independent follow-up on debates related to global warming or Jefferson's ancestry) and informal settings (e.g., learning the causes of home garden infestations or the impact of recent tax laws on personal finances). We acknowledge that different learning goals exist, recognize the implications of these perspectives on design and learning, and identify strategies that are best aligned with and appropriate for a given learning need.

Grounded Design

Grounded design is "the systematic implementation of processes and procedures that are rooted in established theory and research in human learning" (Hannafin et al., 1997, p. 102). Grounded approaches emphasize the alignment of core foundations and assumptions, and the linking of methods and approaches in ways that are consistent with their corresponding epistemological perspectives. It does not advocate or presume the inherent superiority of a specific epistemology or methodology for design. Rather, grounded design provides a framework for reconciling diverse design practices with the basic tenets of their associated belief systems. We have previously outlined the importance of alignment among psychological, pedagogical, technological, pragmatic, and cultural foundations of a learning environment.

Grounded student-centered learning environments support learners as they negotiate multiple rather than singular points of view, reconcile competing and conflicting perspectives and beliefs, and construct personally-relevant meaning accordingly. Key overarching assumptions and values are reflected in seemingly diverse environments. For instance, one environment might support collaboration activities to facilitate shared meaning of scientific practices; others might rely upon individually-mediated use of technology tools to generate, test, and refine personal theories. Both environments emphasize learning as a goal-directed activity, yet each provides a somewhat different context to support learner-constructed meaning (e.g., rich technological support, rich social support). What is important from a grounded design perspective is that the design decisions, features, and sequences of the learning environment align with theoretically-grounded perspectives on learning and associated pedagogy.

Grounded design, therefore, involves the simultaneous alignment of each foundation in order to optimize coincidence across all foundations; as the intersection across foundations increases, the better grounded the design. A wide array of psychological perspectives can be drawn upon, for which a multitude of pedagogical alternatives is available. All perspectives and methods, however, are not interchangeable; in grounded design they are interdependent. By default or design, many learning environments simply do not adhere to the definition, foundations, assumptions, and methods of grounded instruction. This is the case both for designs that purport to be instruction but fail to reflect the requisite alignment as well as for learning environments that are rooted in fundamentally different perspectives. Compared with instructivist methodologies, for example, student-centered approaches support different learning goals, utilize different methods, and adopt different assumptions about the nature of knowing and understanding. However, as with instruction, not all alleged student-centered learning environments are well grounded. Many environments are rooted in appropriate foundations, yet the methods are incompatible with the associated assumptions. Gaps frequently exist between the presumed underlying constructivist epistemology and the associated affordances and activities (Perkins, 1985; Salomon, 1986). For example, learner-controlled, directed practice may be mischaracterized as a constructivist methodology despite the concurrent focus on explicit instruction; conversely, a complete absence of external support may be mistaken for student-centered learning when needed scaffolding is not provided. For constructivist as well as other learning environments, grounded educational practices align foundations, assumptions, and methods as a matter of design. Explicating alternative theories for grounding design of SCLEs is the primary purpose of this book.

We consider four conditions as basic to grounded design practice. First, designs must be rooted in a defensible and publicly acknowledged theoretical framework. Learning environments are grounded to the extent that core foundations are identified and aligned; they link corresponding foundations, associated assumptions, and methods. Next, methods must be consistent with the outcomes of research conducted to test, validate, or extend the theories upon which they are based. Grounded design methods have been evaluated in instances, cases, and research; grounded design practice builds upon tested and proven approaches. In addition, grounded designs are generalizable, that is, they transcend the individual instances in which isolated success may be evident, and can be adapted or adopted by other designers. This does not suggest a literal, algorithmic mapping of methods according to strictly defined conditions, but rather the heuristics-based application of design processes appropriate in comparable circumstances. Finally, grounded designs and their frameworks are validated iteratively through successive implementation. Methods are proven effective in ways that support the theoretical framework upon which they are based, and extend the framework itself as successive implementations clarify the approach. The design processes and methods continuously inform, test, validate, or contradict the theoretical framework and assumptions upon which they were based, and vice versa.

Key Assumptions and Methods of Student-Centered Learning Environments

Student-centered learning environments reflect several key assumptions about the nature of learning, the structure of the environment, and role of the learner (Hannafin & Land, 1997). Despite differences manifested in various student-centered designs, several core values and assumptions can be identified: (a) centrality of the learner in defining meaning; (b) scaffolded participation in authentic tasks and sociocultural practices; (c) importance of prior and everyday experiences in meaning construction; and (d) access to multiple perspectives, resources, and representations.

The Centrality of the Learner in Defining Their Own Meaning

In student-centered environments, the overarching focus is to support the learner to actively construct meaning. External learning goals may be established, but the learner determines how to proceed based on individual needs and questions that arise while generating and testing beliefs (Hannafin, Land, & Oliver, 1999). For example, the WISE project operationalizes a framework of scaffolded knowledge integration (Linn, 2006) in the design of computer-based, student-centered support for science learning. In the thermodynamics environment, for instance, students engage with a virtual laboratory to inquire, experiment, and compare predictions with simulated outcomes about the temperature of objects around them. Rather than simply read about thermodynamics, students are encouraged to make connections to everyday experiences, collect real data, and conduct virtual scientific investigations about fundamental thermodynamics concepts. As they conduct an investigation, such as the effects of different types of materials on rate of thermal conduction, they use simulation tools to progressively develop, test, and refine explanations of their findings. Although the environment is designed to constrain exploration of thermodynamics concepts in productive and sequenced ways, the focus is on the learner's own efforts to make sense and actively build upon what they know.

Presumably, given opportunities to make choices and pursue individual interests, learners evolve greater responsibility for their own learning. In traditional instructional environments, learners are often denied opportunities to develop the decision-making, self-monitoring, and attention-checking skills necessary to optimize learning experiences (Perkins, 1993; Sawyer, 2006). Learners become increasingly compliant in their learning, viewing the task as one of matching their meanings to those expected by external agents (McCaslin & Good, 1992). In contrast, successful learners evolve a variety of strategies to plan and pursue goals, integrate new and existing knowledge, formulate questions and inferences, and continually review and reorganize their thinking (Bransford et al., 2000).

Consequently, student-centered environments scaffold student thinking and actions to facilitate ongoing management and refinement of what they know (Hannafin, Land, & Oliver, 1999). Because learners new to a domain may lack important strategic knowledge for managing the learning processes, "learners can be overwhelmed by the complexity of options available, making it difficult to direct their investigations, see what steps are relevant and productive, and make effective activity decisions" (Quintana et al., 2004, p. 359). Accordingly, the process of managing inquiry (i.e., proceeding through an open-ended task by keeping track of findings, deciding what to pursue next, determining how available tools and resources are useful in a problem, and reflecting on what is being learned) are supported through structures and guidance embedded into the environment (Quintana et al., 2004). The individual uniquely defines and monitors understanding to promote autonomy and ownership of the learning process, but these processes often will not occur spontaneously without explicit support.

Implications for Design

SCLE designs afford cyclical supports to engage various cycles or progressions of inquiry (Schwartz et al., 1999). Designs use increasingly complex problems around a central concept, beginning with learner articulation of initial ideas. Learners progressively refine and reconstruct initial ideas through activities such as comparing ideas with experts or data, engaging in self-directed inquiry, testing ideas through experimentation, vetting formative ideas publically, and creating artifacts of their understanding. For instance, WISE design features encourage learner-defined meaning using built-in prompts to predict outcomes before experimenting (eliciting learner preconceptions), deciding which factors to investigate, simulating outcomes of student-designed virtual experiments, and comparing and reflecting upon differences between predicted and data-based outcomes. Students are guided to search for patterns in the data to critically examine their initial ideas and to refine their explanations more scientifically.

Schwartz et al.'s (1999) framework for guided inquiry supports students to engage cycles of progressively complex challenges, generate their own ideas on how to address the challenges, compare ideas with others and reflect on the differences, develop, assess, and revise understanding, and ultimately present a final solution or product publically. Similar strategies are apparent in other SCLEs, such as problem-based learning (Hmelo-Silver, 2004). Although the problem or activity is structured and constrained for students, the iterative learning process is driven by students' initial ideas that are progressively refined through access to additional information, representations, experiments, or perspectives.

Scaffolded Participation in Authentic Tasks and Sociocultural Practices

Student-centered learning is rooted in situated learning theory, which explains that knowledge, thinking, and the contexts for learning are inextricably tied and situated in practice (Brown et al., 1989). Barab and Duffy (2000, p. 26; Chapter 2) wrote that situativity theory "suggests a reformulation of learning in which practice is not conceived of as independent of learning and in which meaning is not conceived of as separate from the practices and contexts in which it was negotiated." A community of practice (Lave & Wenger, 1991) involves "a collection of individuals sharing mutually defined practices, beliefs, and understandings over an extended time frame in the pursuit of a shared enterprise" (Barab & Duffy, p. 36) that legitimize, use, and advance the practices of a domain. Understandings, as well as identities, are believed to develop through participation in authentic practice. The practices, situations, and processes of a community frame how knowledge is meaningfully used.

While all learning is contextually based, not all contexts support the application of knowledge equally. Knowledge acquired in decontextualized contexts, for example, tends to be inert and of little practical utility (Whitehead, 1929). For instance, learning to solve classical textbook mathematical equations independently of their authentic context tends to promote isolated, naive, and over-simplified understanding (Brown et al., 1989). Learners may successfully solve near transfer problems (e.g., other textbook problems) where the algorithm can be equivalently matched, but fail to flexibly apply or critically reason through a problem on far-transfer or novel tasks (Perkins & Simmons, 1988). In situated contexts, learning occurs as a consequence of a learner's recognizing knowledge's practical utility as well as the need to use it in an attempt to interpret, analyze, and solve real-world problems.

Implications for Design

Rather than treating knowledge as isolated content to be processed, elaborated, and retrieved, student-centered environments promote authentic practices that situate knowledge-in-use (Sawyer, 2006). In the context of schooling, Barab and Duffy (2000; Chapter 2) use the metaphor of "practice fields" to describe learning environments that engage children in "practicing" the kinds of problems and practices that may be encountered in real-world, out-of-school contexts and communities. They identify several design strategies for designing practice fields: (1) students should do domain-related practices, not just learn about them; (2) students need to take ownership of the inquiry; (3) coaching and modeling of thinking skills is needed; (4) students should be provided with explicit opportunity for reflection; (5) dilemmas are ill-structured and complex; (6) learners must be supported to engage the authentic complexity of the task, rather than simplifying the dilemma with unrealistic problems; (7) students work in teams to address contextualized problems.

Participation in authentic practices cannot be operationalized successfully without scaffolding the "gulf of expertise that lies between the novice learner and the more developed understanding or expertise embodied by an expert in the domain" (Quintana et al., 2006, p. 121). Children or newcomers to a domain cannot be seen as full practitioners in the same way as professional architects, scientists, or athletes. However, Edelson and Reiser (2006) suggest that children can be supported to engage in and reflect on authentic practices, provided they are developmentally and representationally accessible. They suggest that authentic practice involves engaging students in the disciplinary practices of professional practitioners. Although children or newcomers lack the expertise to solve the same problems as practicing scientists or historians, they can engage in activities that are consistent with them and/or that have connections to real-world activities that can be directly experienced.

According to Edelson and Reiser (2006), designing to support authentic practice is complex, but has many potential benefits: (a) authentic practices may be encountered outside of school in personally consequential ways, increasing their relevance; (b) increased motivation may result from applying knowledge to meaningful contexts; and (c) the structure of knowledge, or the epistemology of the domain, can become more obvious as a result of engaging in disciplinary practices. They suggest four design heuristics to support learning in authentic contexts: (a) situate authentic practices in meaningful contexts; (b) reduce the complexity of authentic practices; (c) make implicit elements of authentic practices explicit; and

(d) sequence learning activities according to a developmental progression (p. 336). Similar pedagogical strategies, well-aligned with psychological foundations of situated cognition, are commonly cited foundations for problem-based learning (Savery, 2006) and anchored instruction (Cognition and Technology Group at Vanderbilt, 1992).

Importance of Prior and Everyday Experiences

Individual beliefs and experiences provide uniquely personal frameworks for new understanding. Contemporary views on learning recognize that prior knowledge and experience form the conceptual referent from which new knowledge is organized and assimilated, and that learners' prior knowledge and beliefs influence what they perceive, organize, and interpret (Bransford et al., 2000). Understanding continuously and dynamically evolves, as ideas are generated, expanded, tested, and revised (Land & Hannafin, 1996). Learners hold powerful, often naïve and incomplete, beliefs that are deeply rooted in their everyday experience. While individual models tend to be tacit and sometimes at odds with accepted notions, they provide the basis through which learners interpret and explain new concepts. Such beliefs tend to persist even in the face of contradictory evidence; simply telling children that not all heavy objects sink or that the earth is round often fails. Instead, teachers and designers must use methods of eliciting pre-existing beliefs and actively building upon them (Bransford et al., 2000).

SCLEs often employ problem contexts designed to link everyday experiences and build upon what students know. When learning is anchored in everyday contexts, learners are more likely to understand how concepts are applied and why they are useful, thus facilitating transfer (Bransford et al., 2000). Making connections to everyday contexts guides students to enrich and integrate schooling and life experiences and to develop meaningful, long-lasting interests and understandings (Bell et al., 2009).

Implications for Design

In student-centered design practices, erstwhile tacit beliefs are frequently externalized and formalized so they can be tested. Simulations, for instance, allow learners to generate and test working models of their tacit understanding and get feedback on them (Clark et al., 2009). By varying parameters and hypothesizing outcomes, learners presumably test assumptions and revise thinking based on resultant observations. Some design approaches promote a tiered or phased approach to learning that builds upon informal or everyday experiences of learners and then subsequently extends those experiences with more formalized concepts. For instance, Clark et al. (2009) used video games to initially build strong intuitive knowledge of physics and later introduced more formalized concepts and representations to extend students' understanding of physics concepts. Similarly, augmented reality designs have emerged that overlay virtual media (videos, text, data) onto GPS-tagged locations (Squire & Jan, 2007) in order to extend the meaning of, or ways of experiencing or observing, familiar physical locations.

Student-centered environments often utilize familiar problems or local issues to prompt access to and deployment of personal theories and experiences. Activities and contexts that readily connect to learners' experiences are assumed to increase relevance and engagement. For instance, roller coaster simulations are designed to support children's exploration of force and motion concepts through development of a virtual roller coaster (Kirriemuir & McFarlane, 2003). The context employs a familiar referent (riding roller coasters) to assist learners in relating to-be-investigated concepts to familiar experiences. Other designs have incorporated learners' real dietary choices to investigate health and nutritional science (Land et al., 2009). The everyday context is used to induce learners' related experiences to interpret, explain, and eventually formalize the related scientific knowledge.

Learning is Enriched via Access to Multiple Perspectives, Resources, and Representations

Student-centered learning environments focus on enriching and extending learning through a variety of perspectives, resources, and representations. Such environments may use teacher–student or student–student interactions to model or scaffold reflection and performance (see for example, Palincsar & Brown, 1984). Accordingly, varied perspectives from teachers, experts, or peers can be coordinated to form a knowledge base from which learners evaluate and negotiate varied sources of meaning. Varied methods and perspectives are viewed as critical to developing deeper, divergent, and more flexible thinking processes.

Computer tools are also used in SCLEs to enhance, augment, or extend thinking or perspectives (Pea, 1985). Multiple representations may be supported by visualizing ideas. By accessing alternative ways to represent "hard-to-see" concepts and to manipulate them (e.g., tools that allow learners to change the tilt of the earth's axis and distance from the sun in order to simulate the seasons), learners consider concepts and ideas in ways that would typically be inaccessible. Computing tools such as simulations, GPS data and maps, and virtual worlds allow learners to visualize and experience complex representations of concepts, thus adding to the richness of perspectives available on the topic. The externalized representations enable new forms of discourse and engagement (Roth, 1995).

Implications for Design

SCLEs promote learning via varied perspectives, representations, and resources using strategies such as structuring opportunities to integrate and share personal experiences or observations. For instance, the WISE environment described previously (Linn, 2006) uses Web technology to support sharing of learner-constructed evidence to evaluate scientific phenomena. Students can browse databases of evidence constructed by themselves, as well as with other students and teachers. Learners review the varied, and sometimes conflicting, evidence to determine whether it supports or contradicts their position. As divergent views are deliberated, learners inquire further to reconcile differences and refine explanations. Hedberg and Chang (2007) describe the G-Portal digital repository that represents a collection of geographic objects that can be represented in layers (e.g., beach profiles, vegetation). In one study, students were tasked with solving an authentic problem involving land use planning for a mock beach resort, representing data spatially and collecting resources and notes in group project spaces to inform their problem. Students presented multiple forms of argumentation during inquiry and developed presentation artifacts with recommendations regarding resort siting under specific conditions.

Design Components and Methods

SCLEs are generally comprised of four primary components, though the methods and strategies used vary depending on the goals and contexts in which they are applied (Hannafin et al., 1999). Contexts represent the nature of the overall problems or tasks that guide and orient students to learning. They span a continuum of structure—from contexts that specify problems and outcomes, but allow for individual exploration (e.g., simulations that allow manipulation of a small number of variables around a specific set of concepts) to externally-generated problems (e.g., problem-based approaches that require solutions to an ill-defined problem) to contexts that are uniquely defined (e.g., personally-defined problems in everyday life, such as needing to learn new knowledge and skills to manage a newly-diagnosed medical condition).

Tools offer technology-based support for representing, organizing, manipulating, or constructing understanding. Hannafin et al. (1999) characterize three types of tools typically employed in learning environments:

- Processing tools (i.e., tools that aid in cognitive processing, information seeking, collecting, organizing, integrating, and reflecting);
- Manipulation tools (i.e., tools that function based on user input, changing and testing parameters, and visualizing effects); and

- Communication tools (i.e., tools that promote social interaction and dialog).

Visualization tools are designed to allow detailed viewing of a phenomenon that might not be visible without such representations (Clark et al., 2009). Web 2.0 tools have expanded the types of tools easily available to designers to support student creation and production of artifacts. Such production tools, in combination with available downloadable software, can be integrated into a learning environment to enhance processing and reflection. For instance, students might use existing software tools to create computer games without prior programming experience (Peppler & Kafai, 2007), construct sharable concept maps to represent and organize their thinking, or create podcasts to organize and present what is being learned. Mobile computing tools have expanded the contexts for student-centered learning beyond the desktop and out into real physical surroundings. Mobile apps and handheld tools, for instance, enable GPS capability, scientific measurement, audio and video capture, as well as augmented reality of GPS-tagged locations.

Resources represent source information and content, and may range from static information resources related to the topic under study (e.g., text, video) to dynamically-evolving resources that are socially-constructed (e.g., WIKIs, blogs). Web 2.0 tools, for example, enable creation of sharable resources, and mobile tools support information to be pushed to users at the point of demand, based on GPS location (Pastore, Land, & Jung, 2011).

Scaffolds are support mechanisms designed to aid an individual's efforts to understand and are typically designed to provide the following functions (Hannafin et al., 1999):

- Conceptual guidance on concepts related to the problem;
- Metacognitive guidance on how to reflect, plan, and monitor;
- Procedural guidance on how to use the environment's features and proceed through the environment; and
- Strategic guidance on how to approach the task or refine strategies.

Quintana et al.'s (2004) review of student-centered environments synthesized a framework characterizing three main categories of scaffolds: (a) sense-making, (i.e., scaffolds to enable learners to generate and test hypotheses, manipulate and inspect representations, make comparisons, construct explanations, or highlight disciplinary strategies); (b) process management (i.e., scaffolds to constrain and guide learners to be able to better manage the complexity of the environment); and (c) articulation and reflection (i.e., scaffolds to support reviewing, reflecting, synthesizing, and expressing). Scaffolding serves the role of helping learners to productively engage the complexity, authenticity, and open-endedness of the environment.

Types of Student-Centered Learning Environments

Student-centered learning environments draw upon a variety of design methods, tools, scaffolds, and problems, and often look very different from one another. However, despite apparent differences across learning environments, they generally follow from an overarching theoretical foundation and set of learning goals. This section categorizes and describes various student-centered learning environments to illustrate similarities and differences in foundations and designs.

Problem-based Learning

Savery (2006, p. 9) defines problem-based learning as "an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem." Problem-based learning (PBL) originated within medical school curricula as a method to help medical students learn clinical problem-solving skills in a real-word context. PBL uses an authentic, ill-structured problem as the frame for learning new knowledge and skills connected to a real application. In a medical school example, students might explore a hypothetical patient case. They are then progressively supported to consider, develop, and refine explanations of important physiological concepts linked to observations from the case. Learners engage in a self-directed learning process that proceeds from generating initial explanations about possible causes of the problem (Hmelo-Silver, 2004). Students ask questions to clarify the problem and generate "learning issues" (often recorded on a whiteboard) to investigate further. Students investigate these learning issues outside of class and reconvene to discuss what was learned and to generate new learning issues. As the causes and solutions are generated, students are prompted to explain and reflect upon them according to the relevant concepts and principles.

PBL often relies on a skilled facilitator to scaffold the problem-based inquiry and use of the whiteboard as a metacognitive scaffold to guide students through the process. Resources play a prominent role, as students independently research relevant domain information to help them represent and solve the problem. The approach has been extended to both K-12 and higher education contexts, where the focus is on using realistic problems of practice or a domain as the context for learning (Savery, 2006).

Learning Communities

Learning communities (see Chapter 11) comprise groups of learners who work together to learn and model authentic, domain-related practices (Palincsar & Brown, 1984). Bielaczyc and Collins (1999, p. 271) state that "the defining quality of a learning community is that there is a culture of learning in which everyone is involved in a collective effort of understanding." They identify four characteristics of learning communities: (a) varied areas of expertise are encouraged and facilitated; (b) goals are to advance the collective knowledge of the community; (c) learning how to learn and create knowledge is emphasized; and (d) mechanisms or technologies for sharing what is learned are central.

Knowledge Forum, a well-known example of a learning community, is based on knowledge-building theoretical and pedagogical perspectives (Scardamalia & Bereiter, 2006). This work emphasizes collective building and improvement of ideas, and technology tools support students to post their ideas and notes, comment on and add to others' ideas, organize their own and others' ideas according to different conceptual frames, and to add varied graphical representations. Students are agents of their own understanding, and participate in a culture that generates and contributes to both individual and collective knowledge.

Stickler and Hampel (2010) describe the Cyber Deutsch collaborative language learning environment grounded in socioconstructivist theories, where students interacted with each other through various tools and learned language by practicing language forms and communicating authentically. Students completed various activities in both synchronous FlashMeeting videoconferences and asynchronous discussion forums, and leveraged Web 2.0 tools such as survey editors to question one another as well as blogs and wikis to practice writing collaboratively with ample opportunities for commenting and peer edits.

Communities of Practice (COP)

A community of practice (see Chapters 2 and 12) involves a group of individuals who share practices, beliefs, and understandings in pursuit of a shared enterprise (Barab & Duffy, 2000). In COPs, practice is not considered independent of learning and the contexts in which it is negotiated (Brown, Collins, & Duguid, 1989). The COP framework emphasizes how communities learn outside of the classroom, and emerged from research based on traditional craft apprentices (Lave & Wenger, 1991). Learning in these contexts centers on participation and the ways that newcomers progressively enter into a more central role in the community. As a result of participation, both practices and identities advance (Barab & Duffy, 2000).

Design efforts have focused on using technology with communities of practice to enhance knowledge sharing and to tighten the bonds between existing workplace communities (Hoadley & Kilner, 2005). For example, Company Command (Hoadley & Kilner) is an online COP for US Army officers that brings together company commanders across the globe to help each other advance their practice. Similarly designed COPs include those used to enhance preservice and newly practicing teacher practice (Barab et al., 2002), and automobile sales and service representatives' sharing of stories and best practices (Land et al., 2009).

Gaming, Virtual Worlds, and Simulation Environments

Balasubramanian and Wilson (2005) note that researchers often attempt to differentiate between games and simulations, but find "more commonalities than differences." deFreitas and Griffiths (2008) describe recent simultaneous convergences in gaming that have further blurred the boundaries with implications for education. For example, gaming has converged with cinema by employing similar software tools to create authentic 3D environments. Gaming has also converged with the Web by making collaborative multiplayer environments and virtual worlds (MUVEs) available online with Web 2.0 tools for chatting and generating content related to the experience. Further, gaming has converged with mobile devices by making handheld games accessible to more users and opening up opportunities to apply games outside of traditional classroom spaces in the field. Tools such as Scratch (Calder, 2010) increase opportunities for game players to design and share games that suit personal learning interests. To utilize games and simulations in education, it is necessary to plan strategies and scaffolding that will best expose students to core concepts.

Civilization III is a hybrid game/simulation environment that has been applied in some education contexts for learning about historical development and nation building. The program has rules such as a the number of food units that must be produced to sustain a population of a given size, and the number of land units that can be put into production around a city. Authentic scenarios play out with students sponsoring or defending against war, and recent expansion packs allow users to pit their civilizations against others online. Charsky and Ressler (2011) applied concept maps as scaffolds for 9th grade students to focus on key concepts while interacting with Civilization III in a global history class. Student motivation in concept map groups, however, declined relative to no-map groups, suggesting external scaffolds imposed on a game environment may be a challenge if they decrease the autonomous nature of play.

Spires (2008) describes Crystal Island where students engage in virtual scientific activities at a research station to address the problem of scientists becoming ill while studying microbiology concepts. The simulation includes embedded conceptual and metacognitive scaffolds within character dialogues, and procedural scaffolds in the form of virtual lab tools for testing hypotheses. If students apply a "scattershot approach to testing hypotheses" and exceed test limits, the simulation initiates strategic scaffolds that requires students to reconsider four key components of the simulation task before they can proceed (Spires, Rowe, Mott, & Lester, in press).

Digital Repositories

In the past two decades, dramatic increases have been evident in the number of digital repositories accessible via the Web, allowing educators to access and utilize extensive data sets, maps and images, and other primary source documents featuring authentic, context-rich resources. The potential for digital repositories to support student-centered inquiry, however, is often tempered by the largely unstructured nature of these resource sets and features. Indeed, for a digital repository to support student-centered learning, appropriate learning tasks, tools, and scaffolds must be effectively integrated with the resources.

Oliver and Lee (2011) describe the Plantation Letters primary source repository that represents a collection of letters written to and from American plantation owners in the nineteenth century with a search interface to retrieve letters associated with pre-defined themes. In one lesson grounded in cognitive flexibility theory (Spiro, Feltovich, Jacobson, & Coulson, 1992), students retrieve plantation letters using health-related tags to study conditions contributing to medical problems among enslaved workers. Multiple perspectives on the concept of medical crises are supported by reading across different plantation cases presenting with chronic health problems as well as external cases of recent medical crises brought about by natural disasters. Students develop and defend a rank-ordered plan for resolving a current medical crisis with similar conditions to those described on plantations and other unhealthy sites (e.g., inadequate housing, clothing, food). Students present and discuss their plans in the Plantation Letters Ning social network to reach consensus on the most damaging conditions and the most appropriate and humane interventions.

In another more heavily scaffolded lesson created for the Plantation Letters project, students apply the SCIM-C historical inquiry strategy (Hicks, Doolittle, & Ewing, 2004), guiding their own inquiry into themes of personal interest. Students summarize information about their selected source, note contextual information within the source, make inferences about broader historical questions a teacher may pose, and monitor their assumptions and limits in interpretation. After applying SCIM to multiple sources, student then apply a fifth corroboration stage, looking for similarities or differences across sources that could further interpretations. While SCIM-C represents a scaffolded task process to inquire into digital repositories, teachers can utilize a number of emerging Web-based tools to support this work, such as The History Engine (HE) (Benson, Chambliss, Martinez, Tomasek, & Tuten, 2009). The History Engine provides students with authentic opportunities to publish their interpretations of primary sources much like historians, and engage with historical experts and other students in further analysis and corroboration.

Constructionist Learning Environments

Learning is presumed to become more meaningful and motivational when students construct designs or projects (Kafai, 2006). Constructionist environments are designed to encourage knowledge-in-use by developing physical or digital objects that represents understanding (Kolodner, 2006; Papert, 1993). Artifacts might include physical objects like a model rocket or digital objects such as student-created computer games or videos.

Web 2.0 refers to emerging, democratic Web capabilities for users to collaboratively construct and share new information online in varied forms (e.g., user-contributed videos, reflective blogs, collaborative wiki pages). Web 2.0 tools afford functionality that allows students to generate a product or solution following discussion, play, and/or research. A Web 2.0 tool by itself may not apply to all SCLEs, but educators have designed Web 2.0 learning environments that utilize collections of tools to provide rich context, collaborations with experts and/or peers for multiple perspectives and scaffolds, and constructionist projects reflecting emergent student understandings.

Lindsay and Davis' (2007) Flat Classroom project leverages multiple Web 2.0 tools. Middle and high school teachers around the world register their classes to discuss world-flattening concepts from Friedman's (2007) popular text examining trends that have resulted in a more connected world (e.g., Google, globalization, mobile computing, social networks). Students collaborate across schools using both asynchronous and synchronous tools such as email and Skype to compare views, and co-construct wiki spaces and video artifacts to represent their understanding in varied themes such as innovation, entrepreneurship, and play. Students must incorporate "outsourced" video segments from partner schools in their video projects to encourage further communication and collaboration. Virtual summits are convened where students share their work and receive feedback from expert judges.

Summary

This chapter provided an overview of the theoretical foundations, assumptions, and design methods that underlie many student-centered learning environments. Since the first edition of this book in 2000, significant advances have been made in articulating and researching pedagogical frameworks (Sawyer, 2006) as well as in utilizing technological capabilities to collaboratively construct, share, and represent what is learned. We have an increased understanding of the frameworks, potential problems, and design techniques associated with scaffolding the complex and open-ended nature of student-centered learning (Quintana et al., 2004). Also emerging more fully in the last decade are research methodologies that have been designed to address complexities in studying interactions among teachers, learners, technology, and learning processes in the naturalistic context (Barab, 2006). Such research allows theory and design to refine simultaneously. Although considerable progress has been made to advance our understanding, many questions and issues remain. It is imperative that such efforts continue not only to ground design practices more completely but also to better understand the promise and limitations of student-centered learning environments in differentiated contexts.

References

Balasubramanian, N., & Wilson, B. G. (2005). Games and simulations. ForeSITE, 1. Retrieved March 25, 2011, from http://site.aace.org/pubs/foresite/

Barab, S. (2006). Design-based research: A methodological toolkit for the learning scientist. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 153–170). Cambridge, MA: Cambridge University Press.

Barab, S. A., & Duffy, T. (2000). From practice fields to communities of practice. In D. Jonassen & S. Land (Eds.), Theoretical Foundations of Learning Environments (pp. 25–55). Mahwah, NJ: Lawrence Erlbaum Associates.

Barab, S. A., Barnett, M. G., & Squire, K. (2002). Building a community of teachers: Navigating the essential tensions in practice. The Journal of the Learning Sciences, 11 (4), 489–542.

Bell, P., Lewenstein, B., Shouse, A., & Feder, M. (Eds.). (2009). Learning Science in Informal Environments: People, Places, and Pursuits. Washington DC: National Academic Press.

Benson, L., Chambliss, J., Martinez, J., Tomasek, K., & Tuten, J. (2009). Teaching with the History Engine: Experiences from the field. Perspectives on History, 47(5). Retrieved March 24, 2011, from http://www.historians.org/perspectives/issues/2009/0905/

Bielaczyc, K. & Collins, A. (1999) Learning communities in classrooms: A reconceptualization of educational practice. In C. M. Reigeluth (Ed.): Instructional-design Theories and Models: A new paradigm of instructional theory (pp. 269–292). Mahwah, NJ: Lawrence Erlbaum Associates.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). How People Learn: Brain, mind, experience, and school. Washington DC: National Academy Press.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, 18(1), 32–41.

Calder, N. (2010). Using Scratch: An integrated problem-solving approach to mathematical thinking. Australian Primary Mathematics Classroom, 15(4), 9–14.
Charsky, D., & Ressler, W. (2011). "Games are made for fun": Lessons on the effects of concept maps in the classroom use of computer games. Computers & Education, 56(3), 604–615.
Clark, R. & Hannafin, M. (2011). Debate about the benefits of different levels of instructional guidance. In R. Reiser & J. Dempsey (Eds.), Trends and Issues in Instructional Design and Technology (3rd edn), (pp. 367–382). Upper Saddle River, NJ: Pearson.
Clark, D. B., Nelson, B., Sengupta, P. & D'Angelo, C. M. (2009). Rethinking Science Learning Through Digital Games and Simulations: Genres, Examples, and Evidence. Invited Topic Paper in the Proceedings of the National Academies Board on Science Education Workshop on Learning Science: Computer Games, Simulations, and Education. Washington DC.
Cognition and Technology Group at Vanderbilt (1992). The Jasper experiment: An exploration of issues in learning and instructional design. Educational Technology Research & Development, 40(1), 65–80.
Collins, A. (2006). Cognitive apprenticeship. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 47–60). Cambridge, MA: Cambridge University Press.
deFreitas, S., & Griffiths, M. (2008). The convergence of gaming practices with other media forms: What potential for learning? A review of the literature. Learning, Media and Technology, 33(1), 11–20.
Dick, W. (1991). An instructional designer's view of constructivism. Educational Technology, 31(5), 41–44.
Edelson, D., & Reiser, B. (2006). Making authentic practices accessible to learners: Design challenges and strategies. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 335–354). Cambridge, MA: Cambridge University Press.
Friedman, T. L. (2007). The world is flat: A brief history of the 21st century (3rd release). New York, NY: Picador/Farrar, Straus and Giroux.
Hannafin, M. J., & Land, S. (1997). The foundations and assumptions of technology-enhanced, student-centered learning environments. Instructional Science, 25, 167–202.
Hannafin, M. J., Hannafin, K. M., Land, S., & Oliver, K. (1997). Grounded practice in the design of learning systems. Educational Technology Research and Development, 45(3), 101–117.
Hannafin, M. J., Land, S. M., & Oliver, K. (1999). Open learning environments: Foundations, methods, and models. In C. Reigeluth (Ed.), Instructional Design Theories and Models (Vol. II). Mahwah, NJ: Erlbaum.
Hedberg, J. G., & Chang, C. H. (2007). The G-Portal digital repository as a potentially disruptive pedagogical innovation. Educational Media International, 44(1), 3–15.
Hicks, D., Doolittle, P. E., & Ewing, T. (2004). The SCIM-C strategy: Expert historians, historical inquiry, and multimedia. Social Education. 68(3), 221–225.

Hirsch, E. D. (2001). Romancing the child: Progressivism's philosophical roots. EducationNext, 1(1). Retrieved March 24, 2011, from http://educationnext.org/romancing-the-child/

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? Educational Psychology Review, 16(3), 235–266.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). Educational Psychologist, 42, 99–107.

Hoadley, C. & Kilner, P. G. (2005). Using technology to transform communities of practice into knowledge-building communities. SIGGROUP Bulletin, 25(1), 31–40.

Iiyoshi, T., Hannafin, M. J., & Wang, F. (2005). Cognitive tools and student-centered learning: Rethinking tools, functions, and applications. Educational Media International, 42(4), 281–296.

Jonassen, D. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm? Educational Technology Research and Development, 39, 5–14.

Kafai, Y. B. (2006). Constructionism. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 35–46). Cambridge, MA: Cambridge University Press.

Kirriemuir, J. K. & McFarlane, A. (2003) Use of Computer and Video Games in the Classroom. Proceedings of the Level Up Digital Games Research Conference, Universiteit Utrecht, Netherlands. Available from: http://www.silversprite.com/

Kirschner, P. A., Sweller, J. & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. Educational Psychologist, 41(2), 75–86.

Kolodner, J. L. (2006). Case-based reasoning. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 225–242). Cambridge, MA: Cambridge University Press.

Krajcik, J., & Blumenfeld, P. (2006). Project-based learning. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 317–334). Cambridge, MA: Cambridge University Press.

Land, S. M., & Hannafin, M. J. (1996). A conceptual framework for the development of theories-in-action with open-ended learning environments. Educational Technology Research & Development, 44(3), 37–53.

Land, S., Draper, D., Ma, Z., Hsui, H., Smith, B., & Jordan, R. (2009). An investigation of knowledge-building activities in an online community of practice at Subaru of America. Performance Improvement Quarterly, 22(1), 1–15.

Lave, J. & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

Lindsay, J., & Davis, V. (2007). Flat classrooms. Learning and Leading with Technology, 35(1), 28–30.

Linn, M. (2006). The knowledge integration perspective on learning and instruction. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 243–264). Cambridge, MA: Cambridge University Press.

McCaslin, M., & Good, T. (1992). Compliant cognition: The misalliance of management and instructional goals in current school reform. Educational Researcher, 21(3), 4–17.
Merrill, M. D. (1991). Constructivism and instructional design. Educational Technology, 31(5), 45–53.
Oliver, K., & Lee, J. (2011). Exploring history in plantation letters. Learning and Leading with Technology, 38(6), 24–26.
Palincsar, A., & Brown, A. (1984). Reciprocal teaching of comprehension-fostering and monitoring activities. Cognition and Instruction, 1(2), 117–175.
Papert, S. (1993). The Children's Machine: Rethinking schools in the age of the computer. New York: Basic Books.
Pastore, R., Land, S. M., & Jung, E. (2011). Mobile computing in higher education. In D. Surry, R. Gray, & J. Stefurak (Eds.), Technology Integration in Higher Education: Social and organizational aspects (pp. 160–173). Hershey, PA: IGI Global.
Pea, R. (1985). Beyond amplification: Using the computer to reorganize mental functioning. Educational Psychologist, 2(4), 167–182.
Peppler, K. A., & Kafai, Y. B. (2007). From SuperGoo to Scratch: Exploring creative digital media production in informal learning. Learning, Media, & Technology, 32(2), 149–166.
Perkins, D. N. (1985). The fingertip effect: How information processing technology shapes thinking. Educational Researcher, 14, 11–17.
Perkins, D. N. (1993). Person-plus: A distributed view of thinking and learning. In G. Salomon (Ed.), Distributed Intelligence (pp. 89–109). New York: Cambridge.
Perkins, D., & Simmons, R. (1988). Patterns of misunderstanding: An integrative model for science, math, and programming. Review of Educational Research, 58, 303–326.
Quintana, C., Reiser, B., Davis, E., Krajcik, J., Fretz, E., Duncan, R., Kyza, E., Edelson, D., & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. Journal of the Learning Sciences, 13(3), 337–386.
Quintana, C., Shin, N., Norris, C., & Soloway, E. (2006). Learner-centered design: Reflections on the past and directions for the future. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 119–134). Cambridge, MA: Cambridge University Press.
Roth, W.-M. (1995). Affordances of computers in teacher–student interactions: The case of Interactive Physics™. Journal of Research in Science Teaching, 32(4), 329–347.
Salomon, G. (1986). Information technologies: What you see is not (always) what you get. Educational Psychologist, 20, 207–216.
Savery, J. (2006). An overview of problem-based learning: Definitions and distinction. Interdisciplinary Journal of Problem-based Learning, 1(1), 9–20.
Sawyer, R. K. (2006). Introduction: The new science of learning. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences. Cambridge (pp. 1–18). MA: Cambridge University Press.
Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 97–118). Cambridge, MA: Cambridge University Press.

Schwartz, D., Lin, X., Brophy, S., & Bransford, J. (1999). Toward the development of flexibly adaptive instructional designs (pp. 183–213). In C. Reigeluth (Ed.), Instructional-design Theories and Models: A new paradigm of instructional theory, Volume II. Mahwah, NJ: Lawrence Erlbaum Associates.

Spires, H. A. (2008). 21st century skills and serious games: Preparing the N generation. In L. A. Annetta (Ed.), Serious Educational Games (pp. 13–23). Rotterdam, The Netherlands: Sense Publishing.

Spires, H. A., Rowe, J. P., Mott, B. W., & Lester, J. C. (in press). Problem solving and game-based learning: Effects of middle grade students' hypothesis testing strategies on science learning outcomes. Journal of Educational Computing Research.

Spiro, R. J., Feltovich, P. J., Jacobson, M. J., & Coulson, R. L. (1992). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In T. M. Duffy & D. H. Jonassen (Eds.), Constructivism and the Technology of Instruction: A conversation (pp. 57–76). Hillsdale, NJ: Erlbaum.

Squire, K. D. & Jan, M. (2007). Mad city mystery: developing scientific argumentation skills with a place-based augmented reality game on handheld computers. Journal of Science Education & Technology, 16(1), 5–29.

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 409–426). Cambridge, MA: Cambridge University Press.

Stickler, U., & Hampel, R. (2010). CyberDeutsch: Language production and user preferences in a Moodle virtual learning environment. CALICO Journal, 28(1), 49–73.

Whitehead, A. N. (1929). The Aims of Education. New York: MacMillan.