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Bridging Theory and Practice: Developing Guidelines to Facilitate the Design of Computer-based Learning Environments

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Abstract

Abstract. The design of computer-based learning environments has undergone a paradigm shift; moving students away from instruction that was considered to promote technical rationality grounded in objectivism, to the application of computers to create cognitive tools utilized in constructivist environments. The goal of the resulting computer-based learning environment design principles is to have students learn with technology, rather than from technology. This paper reviews the general constructivist theory that has guided the development of these environments, and offers suggestions for the adaptation of modest, generic guidelines, not mandated principles, that can be flexibly applied and allow for the expression of true constructivist ideals in online learning environments.

Résumé. La conception d'environnements d'apprentissage informatisés a subi un changement de paradigme, éloignant les étudiants d'un enseignement qui tendait à mettre en avant la rationalité technique fondée sur l'objectivisme, pour les rapprocher d'applications informatiques ayant pour but de créer des outils cognitifs utilisés dans des environnements constructivistes. L'objectif résultant de ces principes de conception d'environnements d'apprentissage informatisés est d'amener les étudiants à apprendre avec la technologie plutôt que d'apprendre de la technologie. Cet article passe en revue la théorie constructiviste générale qui a servi de guide au développement de ces environnements et offre des suggestions visant à adapter des directives mineures et génériques, et non des principes établis, facilement applicables et permettant l'expression d'idéaux véritablement constructivistes dans des environnements d'apprentissage en ligne.

Introduction

Historically, technology-enhanced learning has been developed around the transmission and retention of information through taught knowledge and skills. The instructional design models for these traditional computer-based learning strategies have been built upon realist and objectivist views of knowledge, and expressed through the decontextualized acquisition of passive, inert knowledge. The assumption was that reading, watching videos or controlling a button on these easy to deliver, flashy page-turners constituted `active learning' (Jona, 2000; Jonassen, Carr & Yueh, 1998). These models rarely bridged the gap between theory and practice. In many cases they failed to recognize the need for application in order to understand how to effectively utilize knowledge (Jonassen, 1994). The use of computer instruction to teach irrelevant subject matter that is easily tested, and is measured using inappropriate assessment, has resulted in many missed technological opportunities (Lefoe, 1998).

Gradually this view of learning has shifted to our current understanding that knowledge is constantly advancing. The level of advancement of built knowledge can be seen to directly relate to a society's economic viability (Scardamalia & Bereiter, 2002). We are starting to scaffold this new level of analysis of our learning environments, questioning the kind of education that best prepares students for life in the knowledge society. Preparation for this new knowledge is most effective when students are able to work towards specific, authentic and intrinsic goals where they have choice and must take responsibility for their creation and building of knowledge (Jona, 2000). When these instructional strategies are applied to technology there is a decisive shift from computer-based instruction where students learn from technology, to the application of computers to create cognitive tools and constructivist environments where students learn with the technology (Ip & Morrison, 2001).

This paper examines the paradigm shift that has occurred in the design of computer-based learning, and considers the constructivist theory that has guided the development of recent design goals in online environments. Unlike the current constricting principles that have been developed to guide instructional designers, it offers suggestions for the adaptation of modest and generic guidelines that can be flexibly applied, allowing the designer to address the needs of each content-specific situation creating an unbounded, open experience for the learner, and the expression of true constructivist ideals in the online learning environment.

Overview of Traditional Computer-Based Instructional Design

Traditionally computer-mediated instructional design has included a certain level of technical rationality, the development of means to address predetermined goals (Schön, 1987), expressed through objectivist ideals that view knowledge and reality existing external to the learner (Jonassen, 1994). Design was a function of fixed achievement, unambiguous ends and the application of concrete instances. The learning process was expressed as a clear demarcation between theory and practice, moving the learner from basic knowledge, to applied knowledge, and finally the practice of this knowledge (Wilson, 1997).

This type of instructional design was a direct expression of behaviourism and the assumption that learners respond to stimuli with a certain level of predictability (Dalgarno, 1996). Early research supported this relationship between technology and education that was founded on the transmission of information (Cognition and Technology Group at Vanderbilt, 1996). The tendency was to assume that there was a correct learning sequence model, and design focused around the transfer of all students to this best model (Jonassen, 1991). This design was reflected in traditional computer-based tutorials, like drill and practice sequences, that were based on programmed behavioural instruction (Dalgarno, 1996).

The application of these specific conceptual schemes to the design of learning environments acted to constrain and shape the content. In the process, the environment was distorted to fit preconceived notions of how learners acquired information. These prescriptive theories provided recipes and heuristics to specify how the end product should be expressed (Wilson, 1997). The computer was used as a tool to complete a task or get something done and did not necessarily address the broader environmental context of the individual (Jonassen, 1991).

As a result, instructional designers often found it difficult to relate to learners needs and the subtleties of the topic content. Therefore it was determined that design and development principles needed to be provided that aligned with teacher and instructors understanding of student requirements (Wilson, 1997).

Creating Cognitive Tools and Constructivist Environments

In the past, students have learned through computer-based instruction using models that provided prescriptive principles for the design of learning that resulted in a specific look and feel to the learning strategy (Wilson, 1997). This framework was focused on the need to complete a task, and the design of a solution to achieve the required skill and knowledge acquisition, with little concern for how the design would impact the development of the computer environment.

The current movement in technology is to create cognitive tools, computer environments that are adapted and developed for intellectual partnerships. These partnerships move past the idea of technology as a finger-tip tool that is used with ease (Perkins, 1985). Instead they seek to develop an environment that enables and facilitates critical thinking and higher-order learning (Ip & Morrison, 2001). These constructivist learning environments create engaging and content-relevant experiences (Papert & Harel, 1991) and utilize scaffolding tools and resources to support unique learning goals and knowledge construction (Land, 2000). These elements are central to the transformation of a learner's mental scheme through cognitive growth (Brooks & Brooks, 1999).

A student's search for understanding is what motivates him/her to learn and is central to the development of a successful constructivist environment. The creation of motivational factors in constructivism is illustrated through its three main tenets: understanding is created through learning that is grounded in interaction with the environment; cognitive puzzlement stimulates and organizes learning; and knowledge develops through social negotiation and reflection upon individual practices (Gruba & Lynch, 1997). The capabilities of technology allow for the creation of these environments based upon complex concepts that can be represented, manipulated and explored (Hannafin, Hall, Land & Hill, 1994). In addition, technology allows for tools that enhance learner reflection and amplification of built knowledge (Jonassen, 1995). Instead of learning from computers, students are able to learn with computers in these constructivist environments.

Although in theory constructivism is perceived to be the ideal model to guide the design of computer-based learning environments, in certain instances, and for certain content, constructivism often falls short. At first sight, constructivist learning environments afford designers the opportunity to develop and structure learning environments where students actively participate to construct, build and reflect on knowledge. However in a constructivist environment we can only control what we teach, we can't control what students learn, as the ideological view of constructivism is that learners cannot develop and understand meaningful knowledge unless they discover it for themselves. This involves deep individual inquiry that often exerts high cognitive demands that many students are not capable of achieving at their present stage of development and becomes an issue when students are required to construct a unique set of knowledge asynchronously from the rest of the class (Brooks & Brooks, 1999). Although this knowledge may be socially negotiated, its collective scope and depth is limited to, and often has little value beyond, the group (Scardamalia & Bereiter, 1999). This raises the question of knowledge validity, as it is difficult to justify placing the process of developing knowledge over the end product.

In order to maintain the integrity of constructivist computer-based learning, the environment must remain flexible, customized and dynamic in its structure in order to facilitate decision-making by students (Takala, Hank & Rammos, 2001). Often the design process for these environments requires more time to set up and implement than traditional computer-based educational strategies (Perkins, 1999). This process can be successfully undertaken, but designers must question if the effort is worth the educational outcomes.

The enlightened designer of a constructivist computer-based learning environment must also be aware that their educational practice may retain deep roots in other theories that are the result of their own learning experiences. Although they may be aware of this situation, it can still act to constrain their capacity to embrace the central role of the learner in their own education. The designer cannot always account for the learner's interpretation of knowledge, as they do not share common experiences and interpretations (Scardamalia, Bereiter & Lamon, 1994). In this type of environment prescriptive assessment cannot always be a reality. In constructivism, learning is achieved through the internalization of knowledge, which is not easily measured, as only the individual learner can know what they have constructed. This problem is compounded if we are to take constructivism at face value, as the learner's construction of knowledge is idiosyncratic and based on experience, therefore accurate communication of this knowledge through assessment may not even be feasible.

As recognized, constructivism does not always allow for the type of rigid assessment sought by our current education system that is focused on high-stakes accountability (Brooks & Brooks, 1999). This type of assessment is easily satisfied through the sequential and linear process that characterizes behaviourist models of computer-based learning environments. Summative evaluation is achieved through the assessment of concrete objectives that guide the sequenced task development of learners into sub-sets of skills (Willis, 1995). Theoretical constructivist learning environments do not provide the same type of predetermined objective-based evaluation and instead are best expressed as goal-free assessment of learner outcomes. The assumption is that providing specific goals for the learner creates an objectivist learning process and evaluation bias, constricting the constructivist environment (Jonassen, 1991).

In practice, the possibility of goal-free learning is not a valid reason to remove goals from a learning environment. Even if goals are consciously removed, students unconsciously create goals separate from those of the environment to avoid unproductive effort, and employ adaptive cognitive strategies for effective learning (Scardamailia et al., 1994). So instead, designers must consider the nonlinear natures of constructivist models of computer-based learning environments that are grounded in the development of opportunities for reflection and collaboration. Instead of predefining goals, the environment must assist the learner in becoming aware of objectives as they emerge. The resulting personal understanding of the learner is then most effectively assessed through formative evaluation (Willis, 1995). These methods can include documenting the learning process as it is occurring, using environments that have the potential to record and archive student notes, allow for online asynchronous discourse, or encourage concept building and scaffolding. These online portfolios of student work allow teachers to evaluate student understanding, communication and application of the relevant material with increased accuracy by considering the impact of the learning process. Although these types of assessment often require more effort to develop, and tend to be time intensive, the assessment that occurs provides a more detailed account of the actual competence of the student than traditional assessment practices (Strommen & Lincoln, 1992).

The Expression of Design Principles in Computer Environments

It has been recognized that behaviourist models do not fit with a constructivist approach and constructivist theory that focuses on the design environment and places less emphasis on instructional sequence is often more challenging to practice in computer-based learning environments (Lefoe, 1998). If a designer chooses to develop a constructivist computer-based learning environment they must understand that constructivism recognizes that the world does not fit into compartmentalized epistemological categories. Disregarding this understanding and attempting to force-fit learners into specific knowledge paths will only result in more harm than good. Content analysis must be seen as an act of exploration and exploitation of unstructured knowledge, providing learners with opportunities for higher-order synthesis of information (Wilson, 1997).

Therefore current research in online instructional design has sought to provide design goals to develop models of constructivist computer-based instructional development. Many variations of these goals have been developed including, Cunningham, Duffy & Knuth's (1993) seven pedagogical principles; Duffy & Jonassen's (1994) design model built upon the elements of context, collaboration, and construction, later adding conversation (Jonassen, Davidson, Collins, Campbell & Hagg, 1995); and the eight instruction principles for designing constructivist learning environments within a problem-solving context (Savery & Duffy, 1995). Duffy & Cunningham (1996) further refined these design goals into "metaphors we teach by." (p.178)

Most recently Scardamalia (2002) developed twelve socio-cognitive and technological determinants of knowledge building pedagogy. Although each of these determinants are unique, they all rest upon the main assumption that knowledge building should foster collective cognitive responsibility.

The New Instructional Design Approach

The issue with current design principles for constructivist computer-based environments is that they rely on theoretical assumptions on how learners might, or might not, mindfully engage in these environments (Feenberg, 1999). Like many models, the formal description of constructivism deviates from the actual practice in technology-enhanced environments, and design based on these assumptions is often detrimental to the learner (Brown & Duguid, 1991).

This becomes apparent when trying to decide on common goals and principles to guide instructional designers. Initially constructivist design principles were focused upon instructional strategies that facilitated active construction of meaning (Wilson & Cole, 1991). However the progression of research has led to the development of an extensive list of principles that are considered central to the effective application of constructivism through technology. This creates bounded expectations for the expression of learners in these environments that override the ideals of open-learning environments. If learners fail to adhere to the expectations of the design objectives, the environment is seen to be limited in its learning capacity. Yet the very nature of constructivism defies the use of models to constrain learning environments as the existence and expression of knowledge is context-specific (Jonassen, 1994). Therefore the current regime of bounded constructivist design principles often creates neoconstructivist (Harnad, 1982) computer-based environments, where success in the environment is based upon the expression of specific behaviours the principles attempt to generate in learners.

It has been suggested that the present theory of constructivism contains prescriptions for designing elaborate environments that will not constrain the learner (Wilson, 1997).

Therefore we need to fine-tune our instructional design framework and language to create modest, generic guidelines, not mandated principles, which designers can flexibly apply. This will allow for the creation of responsive environments indicative of the adaptive nature of constructivism that can vary in scope and content relative to various design factors, creating applicable situated learning experiences. The following guidelines, which are loosely based upon the twelve socio-cognitive and technological determinants developed by Scardamalia (2002), can be used as a framework for the design of computer-based environments that emulate constructivism.

1. Create Environments that Include Social Negotiation and Cognitive Responsibility

The importance of Social Constructivism has been addressed at various levels in constructivism discourse. Vygotsky questioned the need for cooperative learning in his work on the effects of encountering the zone of proximal development (Doolittle, 1997), Piaget's theory of learning with multiple perspectives (London, 1988), and cognition through the elaboration theory (Brandon & Hollingshead, 1999), rests upon the importance of the socialization of the learner.

The most recent view of the networked computer laboratory is as a social collaboration _ creating a vision of a purposeful setting that allows for interaction and communication according to the audience (Gruba & Lynch, 1997). Through this social setting the most important pedagogical basis for grounding technology in constructivist ideals has been addressed, allowing a comprehensive approach to technology and instruction. This type of virtual learning has also allowed the physical boundaries of the classroom to be redrawn, enabling a higher level of teamwork where learning is a continuous multi-level and multi-speed process that is not constrained by time (Anderson, 1999).

The focus of technology-enhanced constructivism will continue to rest upon building online communities that move beyond the medium to allow for social interaction (O'Reilly & Newton, 2001). This interaction will continue to be inherent to the success of online learning and knowledge building through the support of learning, and mutual support of learners. The way this connection is formed will be reflected by the shared learning goals of students in order to overcome the absence of other physical distractions.

2. Provide Authentic Experiences and Contexts

Constructivist theory seeks knowledge rooted in experience, the form of this experience constrains its representation, and may limit the knowledge a learner will seek. The rapid advances in computer technology have allowed for the development of electronic tools that can enhance student-centered activities (Land, 2000). In many cases, technology has afforded the opportunity for learning that cannot necessarily be accomplished without the computer (Pea, 1985). It extends the environment in which learners can represent abstract concepts, and therefore supports the way learners think about and develop these concepts.

The first models applied to designing computer-based environments focused on exploiting the learner's access to information. There is still merit underlying this initiative. Knowledge must be situated in nature as it grounds learners in authentic activities that allow for enhanced understanding and application. When involved in complex environments, learners may need to be provided with the prior knowledge required to interact in this new situation (Land, 2000). If this knowledge is not provided, learners may develop an inaccurate or incomplete understanding of the knowledge (Carey, 1986), resulting in the development and retention of faulty themes and misconceptions (de Jong & van Joolingen, 1998; Land & Hannafin, 1997; Nicaise & Crane, 1999).

Designers must take advantage of the rich environment the Web offers, and capitalize on these resources. The potential of the web should be matched with instructional design principles (Moallem, 2001). This will allow for content access to parallel the evolution of the learner's knowledge, resulting in experiences situated in appropriateness (Dushastel & Spahn, 1996).

3. Allow for the Development of Pervasive Knowledge

Many novice learners or those with undeveloped knowledge lack the structure required to pervade their knowledge, bridging occasions, subjects and environments (Scardamalia, 2002). Constraining this knowledge in anchored investigation helps students to organize and apply knowledge to familiar experiences (Brickhouse, 1994). Prior experiences must also be connected to experiential repertoire, allowing for relevant facts, information and skills to be brought to the forefront of learning within broader contexts, and ideas of larger scope (Brooks & Brooks, 1999).

In many cases this knowledge transfer must be simulated through analogies, metaphors and questions (Land, 2000) or students will fail to engage in reflective thinking and metacognition (Atkins & Blissett, 1992; Hill & Hannafin, 1997). Therefore interactions between the teacher and learner are required to guide learning, providing an authentic representation of the perceptions, strategies and interpretations of the learner. Through this interaction, new ideas or cultural tools can be introduced that scaffold learners metacognitive development and the self-regulation of their knowledge growth. These processes must be provided in a distinct guided framework that learners can relate back to (Jared & Jared, 1997). This will help learners recognize the importance of these scaffolds and benefit from their use (Oliver, 1999).

Conclusion

Although we have seen a shift from a behaviourist to constructivist view of the design of computer-based learning environments (Jonassen, 1991), behaviourist strategies still provide the foundation and framework for many low-order online learning tasks including basic concept, skills and information acquisition (Atkins, 1993). Designing for computer-based learning is dependent on the application of the environment. Therefore traditional design will always have a place in computer-based learning environments as certain learning situations are best suited to prescriptive and defined learning environments (Willis & Wright, 2000). The key to the successful marriage of multiple objectives in the design of computer-based learning environments is to carefully consider the complex relationship between the user, content and context of the curriculum to be taught and develop a design approach that addresses the needs of the learner while considering any relevant issues that may act to constrain the environment, including assessment needs, design timelines, and user capabilities. Student success in computer-based learning environments does not rest simply on the presence of technology, but more importantly on how the technology is used to create an effective online environment that will impact the learner (Roblyer, 1996)

The issue of creating unified and practical instructional design guidelines for the development of constructivist computer-based environments and cognitive tools will be difficult to address unless we rethink the application of constructivist theory to enhance computer-based learning experiences. Although constructivism is often seen as a single philosophy expressed through a unique method, the theory is best represented in online environments as a "Swiss army knife" (p. 10) that incorporates multiple strategies and interpretations of the effective practice of constructivism (Perkins, 1999). As educators we must move past our concerns of what may be lost in the translation of constructivism into computer-mediated environments and remove the prescriptive principles that have been created to bind the expression of this environment. Instead the development of guidelines should ensure that learners are pointed in the general direction of creating constructivist ideals and not marshaled to this specific goal. Only then can a learning environment exist that allows for representative learning experiences: an environment that can achieve constructivist objectives.

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