Creating Next Generation Blended Learning Environments Using Mixed Reality, Video Games and Simulations

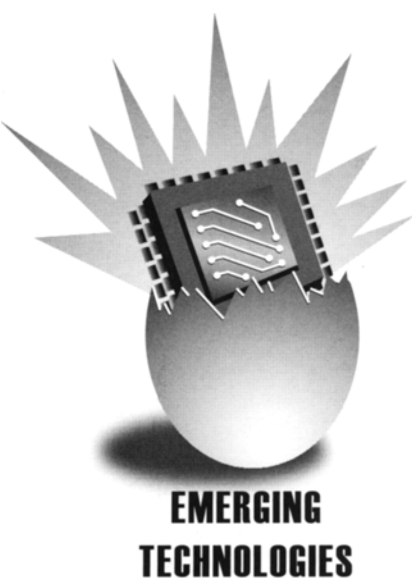
By Sonny E. Kirkley and Jamie R. Kirkley

In this article, the challenges and issues of designing next generation learning environments using current and emerging technologies are addressed. An overview of the issues is provided as well as design principles that support the design of instruction and the overall learning environment. Specific methods for creating cognitively complex, technology-based learning environments that help advance learning are also addressed as well as authoring tools that can help designers address the challenges of instructional design of complex learning environments.

Next generation learning environments

With advances in computer technologies and networked learning, we have exciting opportunities to design learning environments that are realistic, authentic, engaging and extremely fun. Imagine school children role playing environmental scientists walking around an outdoor environment and gathering location-based information on simulated toxins in the water using their handheld computer, sharing data with colleagues and making hypotheses (Klopfer et al., 2002). Imagine a class of architectural students looking at a real plastic model of a city and seeing virtual CAD models of their designs projected into the scene so they can examine how the different building styles interact with the real space. Imagine soldiers using video game technology on a mobile computer with a head-worn display to participate in a training simulation that makes use of a real outdoor training facility. Using the head-worn display, they can see and interact with virtual characters, buildings and vehicles as if they are co-existing in the real world with them (Kirkley, Kirkley, Myers, Lindsay, & Singer, 2003; Kirkley, Kirkley, Myers, Borland, Swan, Sherwood, & Singer, 2005).

These are but a few examples of prototype learning systems using advanced computer technologies. Combined with other emerging technologies like desktop computer games and maturing technologies like web-based learning, instructional designers and educators have an unprecedented opportunity to create blended learning environments (Bonk & Graham, in press) that are highly interactive, meaningful and learner-centered. But how do we balance design tensions between meeting learning objectives and creating engaging and fun learning environments?



Too often, (I paraphrase a colleague's phrase) "fun games are designed and instructional designers come in and suck all the fun out of it" in the quest to meet instructional goals. Herein lies the big challenge for designers of next generation learning environments using next generation technologies.

This article focuses on five key areas that must be considered when designing these learning environments. First, the theoretical framework that guides the instructional design and development approach and management of the overall learning environment. Second, the affordances and limitations of specific technologies that will be employed to create the learning environment. Third, the specific instructional methodologies, strategies and tactics used. Fourth, the instructional design processes and support tools necessary to ensure effective use of the technologies, methods, strategies, and tactics within the theoretical framework.

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Theoretical frameworks

In designing a learning environment, there are a vast number of issues to consider from the theoretical to the practical. In fact, conceptualizing and designing a learning environment is a complex task with a multitude of variables and outcomes to consider as well as real world constraints. In the list below we provide an overall model of factors related to designing a learning environment, although we readily admit there are other variables that come into play:

- need and goals for learning
- learning objectives
- physical and/or virtual space
- tasks and interactions
- assessment methods
- audience and their characteristics
- domain area
- community of learners and practice
- technological capabilities and possibilities

Before addressing how learning environments should be designed, it is important to examine the theoretical assumptions of how people learn. Learning theories are lenses through which we view and think about the learner and learning environment. They guide designers in identifying what is important to consider for learning environment design. Learning theories help designers determine what instructional methods, strategies and tactics are appropriate and how to situate them within the overall learning environment.

In the field of instructional design, there is a long tradition of viewing learning within the behaviorist and cognitive (information processing) theories of learning. Both these perspectives lead to a focus on the design of content so that it is easy to process and learn (Sweller, 1999). In a seminal article in the field of education, Lauren Resnick (1987) offered an alternative perspective of learning, one focused on the goals and activities of the learner rather than on the presentation of content. This is reflective of constructivist and situated theories of learning, which focus on learners actively constructing knowledge in context of the culture and situations in which they are participating. We believe that these constructivist and situated theories offer the best approach to learning environment design and for integrating these new technologies into education and training.

From a constructivist perspective, learning is a process of making sense of the world and negotiating that meaning with others in order to resolve uncertainty and to attain viability of one's own understanding (Duffy & Cunningham, 1996; Piaget, 1932; von Glasersfeld, 1995). Thus, learning is a self-regulatory process of struggling with "the conflict between existing personal models of the world and discrepant new insights" in order to construct new models of understanding (Fosnot, 1996, p. ix). With constructivism, the assumption is that knowledge is personally constructed by the learner and cannot be delivered in exact form from one mind to another (Mayer, 2001). This basic assumption means that the goals and outcomes of learning in constructivist environments often differ greatly than those in an information processing view. From an information-processing perspective, the goal of learning is to adopt a pre-specified knowledge base (e.g., concepts, rules, procedures and well-structured problems) and that this knowledge base will result in generalizable skills that can be applied across content domains (Jonassen, 2000). From a constructivist perspective, the goal for learning is the creation and transfer of context-dependent, flexible and adaptive learning and complex problem solving. In fact, there is a key focus on supporting development of more expert performance within a domain of practice (Spiro, Feltovich, Jacobson, & Coulson, 1992).

To provide a basis of understanding constructivist learning, Savery and Duffy (1996) provide three grounding principles:

1. Understanding comes from our interactions with the environment. We cannot talk about what is learned separately from how it is learned. Rather, what we understand is a function of the content, the context, the activity of the learner and the goals of the learner. If knowledge is indexed by our experience and each experience is interpreted differently by each learner, then knowledge is an intertwining of activity, concepts, culture and goals of the learner (Brown, Collins, & Duguid, 1989).
2. Cognitive conflict or puzzlement is the stimulus for learning and determines the organization and nature of what is learned. The learner's purpose or goal for learning is the starting point for learning. This is central in considering what is to be learned. Thus, the stimulus for learning is critical to understand as we support learners in meeting their own goals by providing environments in which they can resolve cognitive conflict.
3. Knowledge evolves through social negotiation and through the evaluation of the viability of individual understandings. Savery and Duffy (1996) state that the important consideration in this third proposition is that all views, or all constructions, are not equally viable. The social environment is primary in providing alternative views and additional information against which learners can test the viability of their understanding and build a set of propositions (knowledge) that is compatible with our understandings. This forms the foundation of the constructivist perspective of learning.

To support putting theory into practice, Savery & Duffy (1996) provide the following seven constructivist principles of instructional design, which can be used as design guidelines for an overall learning environment:

1. Anchor all learning activities to a larger problem.
2. Design an authentic task.
3. Design the learning environment to reflect the complexity of the environment in which the learner should be able to function at the end of learning.
4. Support the learner in developing ownership for the overall problem.
5. Design the learning environment to support and challenge the learner's thinking.
6. Encourage testing ideas against alternative views and alternative contexts.
7. Provide opportunity for and support reflection on both the content learned and the learning process.

These seven principles can greatly inform the design of a constructivist learning environment that supports learners in developing complex problem solving skills as well as domain expertise.

So where does the use of current and new technologies play into these principles? The design of learning environments should use learning technologies in a way that supports the goals of learning based on these theoretical commitments and design principles. When they are used in a constructivist framework, the use of new technologies reflects principles of supporting learners in developing understanding via purposeful interactions with the environment, including cognitively authentic context, content, and activities that are meaningful to the learner. Thus, simulations, games, problems and cases can all serve as central organizing mechanisms, and potentially provide affordances that enable learners to experience greater authenticity and realism. Also, technologies can be used as the basis for learning environments with the same cognitive complexity as the end goal of the class or module. This is important as we consider how to use technological affordances to provide a learning environment that reflects the same cognitive authenticity as the domain area or environment being trained. For example, one could use a simulation to help learners experience, manipulate and learn from interactions with multiple complex variables that reflect authentic relationships and that change over time. This provides the opportunity to examine alternative views and test one's ideas against other views. Additionally, these technologies may have the capabilities to record and track various learners' actions and choices, which can support reflection and performance assessment. It is important to note that technologies are not required to meet these principles.

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Fun in the learning environment

Although not explicitly mentioned in the literature, we posit that fun should be considered a core principal within the constructivist theoretical framework. Fun has many extremes ranging from laughter-invoking instances to serious situations in which a person is emotionally involved and entertained. Often when discussing learning environments, especially training environments, fun is treated as trivial or, at best, of secondary importance. However, a sense of pleasure is a key driving motivator for people in all environments and thus in constructivist environments which are driven by learner inquiry.

In *A Theory of Fun for Game Design*, Raph Koster (2005) defines fun as "the feedback the brain gives us when we are absorbing patterns for learning purposes" (p. 96). As such, games are learning because the player is constantly seeking to understand the pattern in the game and repeat it until mastery is gained. In constructivist terminology, games invoke puzzlement. Koster discusses many issues and provides principles to follow for designing a fun learning experience. From his point of view, there does not seem to be a design tension between fun and learning as he discusses, using brain-based research, how its enjoyable to make sense of patterns However, just as in any kind of learning, if the game or pattern is too complex or too easy, people become bored. There are efforts to bring more fun into learning and training across many types of learning environments and technologies. For instance, the serious games movement is attempting to bring entertainment video game technology into learning environments by bring together experts in learning environment, game and simulation design.

While fun is a laudable goal, Fowlkes et al (1998) argue that some of the things that make complex games and simulations exciting and engaging actually create unique challenges when they are used as training tools — unpredictability, opaque feedback loops and development of game-specific skills. So the question becomes how to best design learning environments that use fun and engagement to maximize effective training and learning. In this article, we address some of the issues of balancing design tensions as we develop next generation learning environments, and perhaps even think of this as we design current ones as well. However, first we explain what we mean by next generation learning technologies.

Next generation learning technologies

Current technologies such as CD-ROMs/videodiscs, web-based tools and desktop computer game-simulations have been used to support learners in interacting with and experiencing real world problems, cases and scenarios as a context for learning. These technologies are of value because of the capabilities they provide to learners in being able to interact with and manipulate real world

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problems and contexts. However, next generation technologies, such as mixed and virtual reality (Milgram & Colquhoun, 1999), and pervasive computing technologies are now maturing, and they enable even more complex and authentic interactions not only with regard to physical and cognitive fidelity but the ability to embed learning and training experiences into the real world (instead of the other way around). These capabilities provide exciting opportunities for designing innovative learning environments that can hopefully make learning more fun, interactive, effective, relevant and powerful. In fact, is this not the promise we sense for almost every new technology that emerges in training and education?

As new learning technologies emerge, the challenge that designers almost always face is knowing how to design learning experiences in a way that realizes the promises offered by the technological capabilities (see Appelman, this issue). We have seen this process fail such as with web-based instruction — many designers have chosen to simply port current face-to-face approaches to the Web (Gunawardena, 2003) instead of capitalizing on the affordances offered by the technology (e.g., interactivity, embedded resources, access to experts). In defense of designers, we are often faced with barriers such as having little experience or knowledge about the effective uses of, or affordances and limitations of, the new technologies. We also face not knowing how to use effective and appropriate instructional methodologies to design a consistent framework for learning.

Most of us are very familiar with using CD-ROM tutorials, web-based instruction and simulations and games for fun or learning. Whether we have used these in the classroom or the workplace, we understand the basic concepts of how these technologies work to support learning in ways that are both good and bad. We are also very familiar with face-to-face learning as most of us have had at least 12 to 18 years of experience as students with lectures, group work, papers and projects. The one characteristic that describes all of this learning is that it typically happens in a classroom-based learning environment, whether face-to-face or at a distance. The challenge for designers is often to figure out how to bring the real world into the classroom or training environment, however, the potential promise of some newly emerging learning technologies is that we will be able to take learning and training into the real world and embed it within the context, situations, problems and environments where people work and learn. For K-16 students, this may be going into a real wetland and interacting with digital notes embedded into the environment using location-based data access instead of studying it through existing lab notes in the classroom, or experiencing local history onsite and viewing a digital reenactment of a battle instead of viewing images in textbooks or on websites. While technology is not always needed to bring a domain area to life, it can make it easier to provide a compilation of resources, tools and experiences that are embedded into the target environment, using real problems and real techniques for addressing them by using authentic resources and persons by being able to participate, interact and manipulate scenarios.

Mixed and virtual reality technologies

One group of technologies that can provide interesting ways to access and interact with the real environment is mixed and virtual reality technologies. Mixed reality is the experience of a blended virtual and real world (Hughes, 2003), usually through one of the five senses, most often using visual displays and auditory devices. This includes a broad range of applications in which some elements of the real world (e.g., physical space, real objects, environmental conditions) can be blended with digital objects.

To provide a better understanding of the relationships among these technologies, Milgram, Takemura, Utsumi and Kishino (1994) developed a mixed reality continuum. In order to expand on this and demonstrate examples of training environments for each type of reality, we have adapted this model and

Figure 1. The Reality-Virtuality Training Continuum provides examples of each type of training. Augmented vision provides information relevant to a learner's context (e.g., location, task, skill level) on a head-worn display (not co-registered with the environment). In this example, a technician sees a job aid while working on the vehicle. Augmented reality overlays virtual information onto the real world so that people perceive that information as part of the world. In this example, a novice ship navigator sees a virtual highway on the water. Augmented virtuality takes a mostly virtual world and enhances it with some real objects. In this example, real models and virtual models of buildings are augmented with virtual robots to train military personnel.

developed an example Reality-Virtuality Training Continuum (see Figure 1) with examples of training for each technology.

At the far left of Figure 1, we have two real world environments, a factory and a military training exercise. At the far right we have completely virtual environments, a virtual reality factory simulation and a military training game. These virtual reality environments include a range of technologies from completely immersive rooms to desktop computer-based virtual environments that provide a window on the world. The space between these two extremes is called mixed reality where there is some blending of virtuality with the real world. As we move from left to right, the level of augmentation increased until the person is mostly in a virtual environment with a few real world props.

With the augmented vision example, a trainee is shown a job aid for making a repair through a see-through head-worn display. The augmented reality example shows a first-person view for a ship navigator with an overlay of digital data depicting a "highway on the water" shown via a head-worn display. The augmented virtuality example shows a scene in which physical building models are used with virtual robots and virtual buildings to train military maneuvers.

There are many interesting projects focusing on these technologies that have been, or are being, researched and developed. In the early 1990s, the Boeing Company developed augmented reality-based systems to support maintenance and assembly for aircraft wiring harnesses (Caudell & Mizell, 1992). Also during this time, Feiner and colleagues at Columbia University developed KARMA (knowledge augmented reality for maintenance assistance), a test bed system for automating the design of augmented realities that explain maintenance and repair tasks. Within the field of medicine, augmented reality has been used in highly controlled environments to support surgeons by overlaying medical information, such as ultrasound images, directly onto the body to guide the doctor in performing a biopsy (Bajura, Fuchs, & Ohbuchi, 1992). With using these technologies in highly mobile environments, Feiner and colleagues (Feiner, MacIntyre, Hollerer, & Webster, 1997; Hollerer, Feiner, Terauchi, Rashid, & Hallaway, 1999; Hollerer & Pavlik, 1999) have described prototype wearable augmented reality systems to be used for travel, history recreation and touring. To support ship navigation for the U.S. Coast Guard, Information in Place, Inc. (Kirkley, Borland, Pendleton, Waite, Turner & Salaev, 2003) has designed a prototype system called Virtual Aids to Navigation (vAtoN) to provide guidance on navigation of oceans and waterways. The MagicBook project at the HIT Lab (Billinghurst, Kato, & Poupyrev, 2001) seeks to blend the interaction between mixed and virtual reality seamlessly. In the

MagicBook, a video see-through display is used to view a book or other document with embedded symbols that activate the display of a 3D model (e.g., building) in that location (Figure 2). The person using the system can choose to zoom into a scene and the person is at that point in a virtual reality scene (e.g., walk around inside the building).

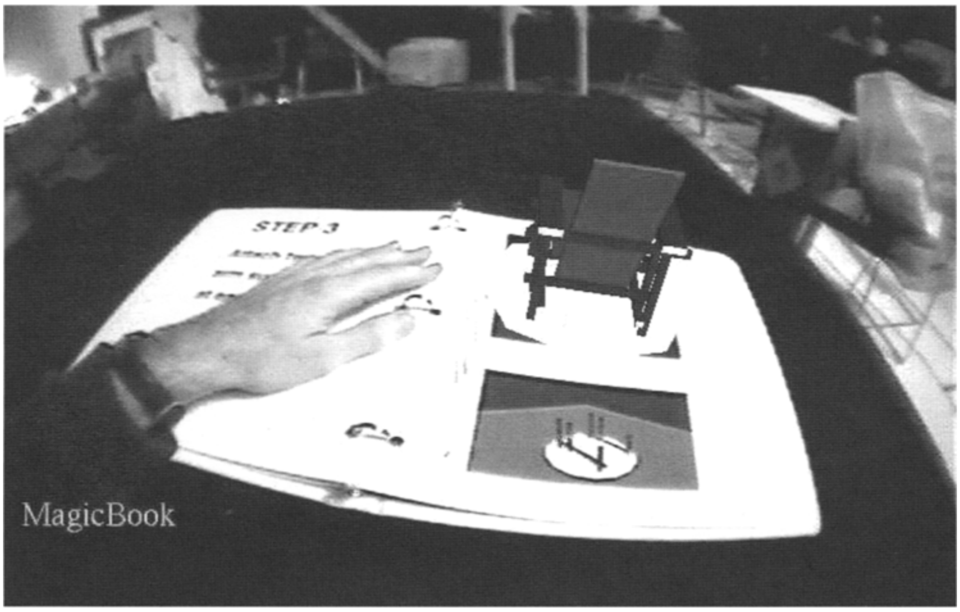

Figure 2. The MagicBook provides augmented views (seen here) and virtual reality views.

While mixed reality technologies have been maturing for thirty years, the vast majority of research efforts have focused on making the technology work with relatively few studies on learning environment impact. A few studies are starting to emerge that show the benefits of these technologies ranging from actual studies with learners to expert reviews of the learning effects we should expect (Kirkley et al., 2005; Klopfer, Squires & Jenkins, 2002; Ong & Nee, 2004). As the technology emerges from the research lab into common use there is a need for a considerable amount of research to be performed in how to best use them for supporting learning.

Game-simulations

One form of mixed and virtual reality is games and simulation. There is a rich base of research on positive and negative aspects of using complex simulations. Simulations have been shown to provide an authentic context to facilitate learning about relationships among a realistic context, environment, actions and outcomes (van den Bosch & Riemersma, 2004). The power of simulations is that they offer opportunities for learners to control and manipulate a wide range of interrelated variables within a complex system in order to better understand how specific actions can impact outcomes (Gredler, 2004). They provide learners with a safe environment and a place where alternative decisions can be tested in support of learning. Simulations are based on relationships among several variables that tend to change over time, and, nonetheless, reflect authentic causal processes (Leemkuil, de Jong & Ootes, 2000) where learners engage in more serious and authentic responsibilities (Bonk & Dennen, 2005). Additionally, simulations may have the capabilities to record and track various learners' actions and choices, which can support enhanced student learning and reflection as well as performance assessment. Fowlkes et al (1998) state that the unpredictability of simulations can impede the control of training variables, and that outcome feedback is not always provided in a way that can be used to help trainees improve performance. Also, limitations of the game design can lead to development of game-specific skills that have no transfer to the reference (simulated) environment (van den Bosch & Riemeresma, 2004).

Simulations are also complex, dynamic and challenging learning environments that pose difficulties for learners who lack a foundational understanding of domain-specific concepts, relationships and problem solving strategies. Since novices often lack sophisticated schema associated with the task or situation at hand (van den Bosch and Riemersma, 2004), they may not be able to make connections among the context, environment, actions and outcomes within a scaled world simulation. They also have difficulties with interpreting the effects their actions have on outcomes, feedback structures and dealing with feedback delays (Brehmer, 1995; Sterman, 2000). Thus, these cognitively complex and technologically advanced learning environments present many challenges for novice learners in effectively learning and managing their performance. Thus, using embedded scaffolds — scaffolding that is embedded within the learning technology such as a job aid in a simulation — that specifically support the development of cognitive and metacognitive skills as well as problem solving strategies can be integrated directly within the learning environment to provide just-in-time, adaptive resources, learning tools and software, pedagogy, content, or the environment (Kirkley, Kirkley, Swan, Sherwood & Singer, 2003).

Instructional design challenges

Over the past several decades, the various technologies discussed in the previous sections have been in various stages of advancement and maturity. Technical limitations still exist and must be addressed before these can be fully implemented for learning and training. While technological issues will continue to advance and be addressed, it is critical that designers develop innovative models of learning environments as well as training methods, processes and tools that effectively use and blend these technologies (Kirkley et al., 2003, 2004, 2005). In fact, designing blended learning environments (Bonk & Graham, in press; Kirkley & Kirkley, in press) is likely to be a major challenge since we do not see old technologies going away but simply being incorporated with the newer technologies into the overall learning environment that uses a wide range of technologies.

Currently, existing instructional methodologies do not adequately address how to design and deliver learning in the context of mixed reality and virtual reality or how to move seamlessly between these modalities as well as traditional technologies within an instructional environment. This requires using, adapting and envisioning models of instructional design that are flexible, adaptive and based on innovative instructional methods as well as new technologies. With movements towards developing learner-centered approaches, user needs and goals will drive the design rather than traditional design processes. From an instructional design perspective, this requires not only developing new methods of training but also using innovative development processes such as rapid prototyping (Tripp & Bichelemeyer, 1990) and participatory design (Reigeluth, 1996; Schuler & Namioka, 1993).

In order to frame the learning environment, instructional methodologies such as problem-based learning (Barrows, 1992; Savery & Duffy, 1996), case-based reasoning (Riesbeck & Schank, 1989) and anchored instruction (Bransford, Sherwood, Hasselbring, et al, 1990) serve as an important design foundation. These methodologies provide a learner-centered framework based on constructivist principles that support different variations of learning using real world problems. Additionally, there are examples of these methodologies that use current as well as emerging technological capabilities as a basis for the design of learning environments. In one example, Kirkley et al (2003) adapted problem based learning methodologies using mixed and virtual reality with traditional technologies to created Problem Based Embedded Training (PBET) for the U.S. Army's Future Force Warrior program.

However, an even more challenging situation lies in the increasing complexity of the process of designing these advanced blended learning environments. One instructional designer can no longer design the environment — now teams with multiple roles and tasks must work together. These teams will include not only instructional designers and subject matter experts but game and interaction designers as well as graphic designers/modelers, programmers and perhaps even script writers and actors. In some ways, we are witnessing the convergence of diverse disciplines such as instructional design, game design and movie production. This is not only the most exciting part, but perhaps the most challenging part, of designing next generation learning environments.

Our goal is not to intimidate but to offer some discussion of challenges and possible solutions to this situation. Following are some challenges that we will face (and already face with current technologies):

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- Different types of developers have different goals and areas of emphasis for their work, and these differences need to be better understood and respected in order to develop an effective learning environment,
- Different types of developers have different vocabularies. A storyboard means one thing to an instructional designer and another to a game designer.
- Different types of developers have different development processes and expectations from these processes. It is critical to discuss these and gain a better understanding of these separately and also to develop a shared development process in order to work effectively.
- The design/development process is a very complex and situated environment with many iterative layers, processes and tools. Thus, having a way to track approaches and decisions made by various designers as well as the evolutions of those decisions is critical.

One possible solution to help resolve some of these challenges is to create an authoring tool to support the design of complex learning environments. With colleagues at Information in Place, Inc. (IIPI), we are developing an authoring tool called *IIPI CREATE*™ to support the various stages of the design process in a way that is flexible and supports iterative design of next generation blended learning environments using games, simulations and various other forms of mixed and virtual realities. We will briefly describe this tool as one example of the types of tools that can be used to organize and support the development process. This tool does not intend to replace the existing tools that various designers/developers use but to provide an organizing, shared framework for various types of individuals as they create these next generation learning environments.

IIPI CREATE was originally prototyped as an authoring tool to support various types of designers of a next generation learning environment for the U.S. Army's Future Force Warrior program. More recently, we have been adapting it for more general use. Furthermore, it is designed to be modifiable so it can support development based on organization-specific design and development processes, terminology, new learning methodologies and emerging technologies. We believe that any authoring tool that is going to adequately address the demanding needs of these next generation learning environments must support this kind of flexibility.

IIPI CREATE has three primary areas:

1. Analysis — this area supports the identification of learning/training needs through needs analysis as well as other types of analyses (e.g., audience, frame factors, technologies, and resource materials).
2. Training Matrix Design — this area supports the translation of learning needs to outcomes/objectives as well as learning tasks and evaluation criteria for each type of audience and for each learning outcome.
3. Design Environment — this area provide multiple types of support to the various types of design processes needed to design next generation learning environments.

Following are some specific tools provided to support the process:

• Module Designer — this designer supports design of modules based on specific instructional methodologies (e.g., PBET). It also enables multiple modules to be sequenced into a learning environment. These environments are too complex to use just generic design support tools. Designer support must be specific to the types of learning technologies and the learning methodologies being used. This includes embedded design support wizards, best practices and design guidelines.

• Storyboard Designer — this supports designing an interactive simulation or scenario by providing ways to describe a series of events, link them to training goals and embed evaluation methods (e.g., a timer-based evaluation event in a game). Multiple views are provided, including a branching chart as well as list view. Designer notes can be embedded throughout, and development resources can be documented and tracked as needed.

• Scaffolding Designer — this supports the development of different types of support for learners at different levels, from novice to expert, that can be directly embedded into a simulation or learning activity.

• Assessment Designer — this supports the design of performance assessments and reflection processes that are linked to specific elements of the learning environment. For example, questions can be developed to support reflection in a simulation based on specific events. Additionally, performance assessment tools for instructors to use in assessing learners on learning objectives based on events within the simulation.

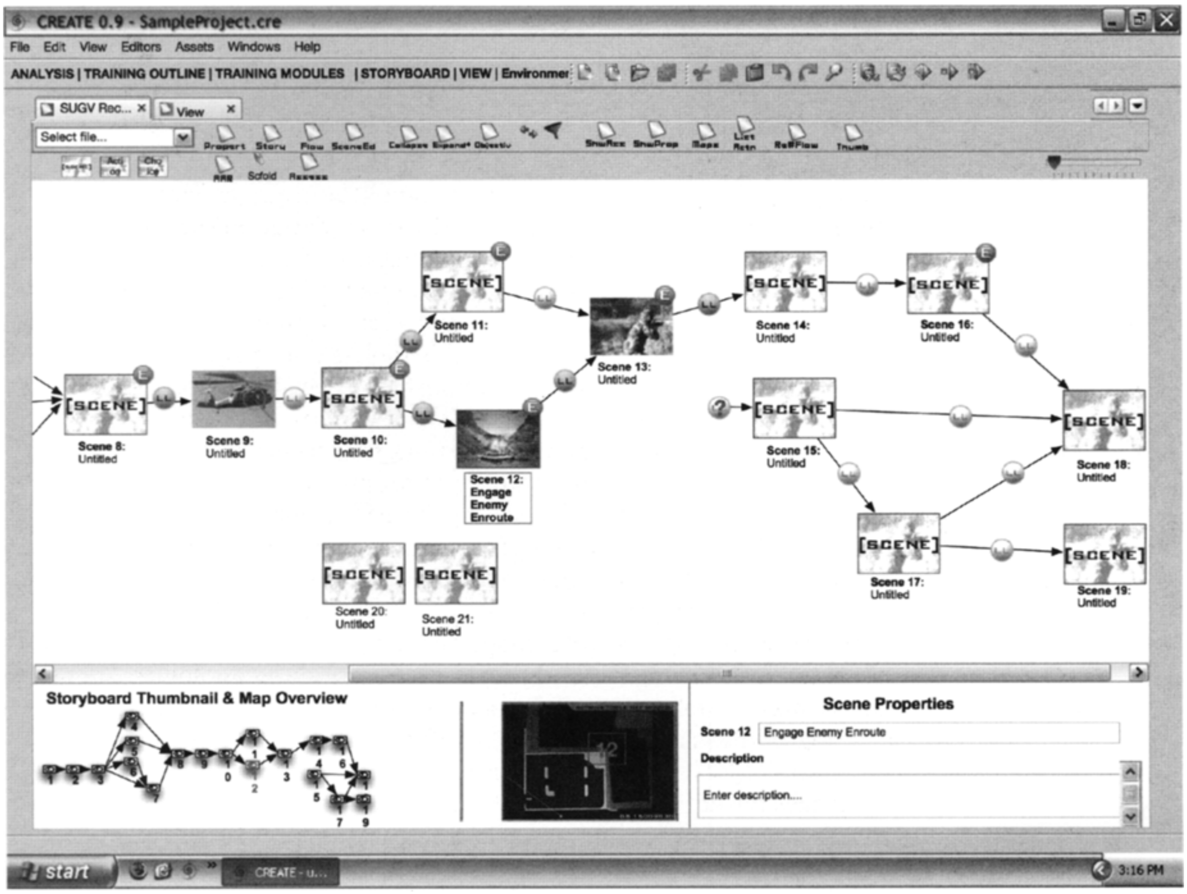

Figure 3. IIPI CREATE *screen showing a learning goal linked to a storyboard, task within a game and associated performance assessments.*

Thus, the primary advantages that we see for using authoring tools for designing next generation learning environments are to:

1. Provide a way to identify, link and implement specific learning objectives within an ill-structured learning environment.
2. Provide support for creating stories and linking those to learning goals as well as embedding assessment methods that are linked to each learning goal and marked by events.
3. Provide support for using specific instructional methodologies to systematically develop blending learning environments using mixed and virtual technologies as well as traditional technologies and approaches (e.g., face-to-face techniques).
4. Create a shared process and space for iteratively designing and documenting the learning environment, whether it is a high-end simulation-based event or a more traditional Web-based learning module;
5. Help balance design tensions between fun and training by enabling different types of designers to communicate and use a shared development

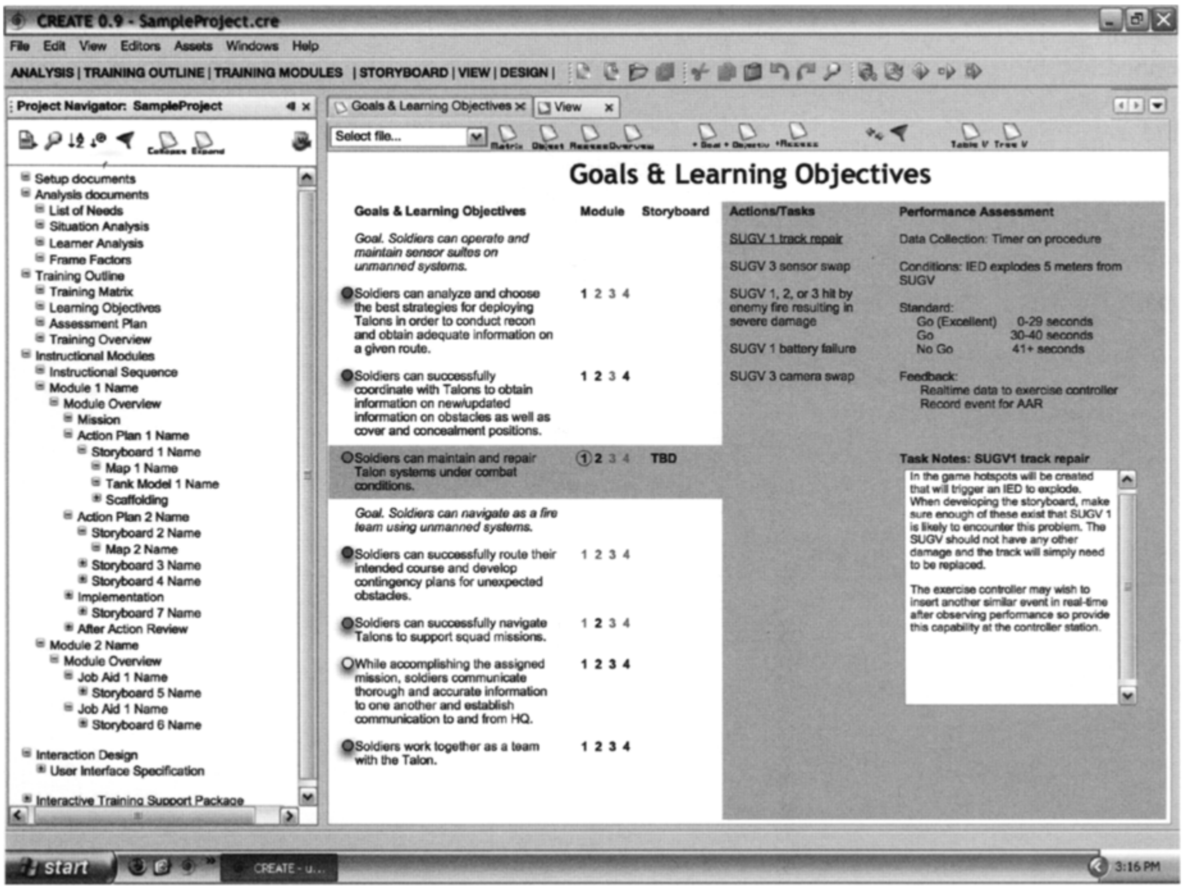

Figure 4. IIPI CREATE *showing a storyboard view of the instructional game design.*

process as well as interlink their purposes and designs for the learning environment.

We do not see *IIPI CREATE* or any authoring tool as being able to solve all the challenges for design of the next generation blended learning environments. However, we do see these tools as providing critical support to help teams manage the complexities of designing and integrating new technologies in order to create effective learning.

Summary

The goal of this article has been to discuss next generation learning environments and next generation training technologies as well as the learning and design challenges faced in using these. Specifically, we discuss theoretical and design principles of constructivist learning environments and how advanced technologies can potentially support meeting these principles as well as the challenges they may pose to various types of designers, instructional, game, graphic and programming. To address methods for designing complex environments, we also address the use of methodologies and authoring systems with various tools to support the design process. In this context, to illustrate how tools can be used to help instructional design teams manage the complexities of developing for these environments. As an example, we discuss one tool, *IIPI CREATE,* that supports this process and organizes the development process.

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References

Bajura, M., Fuchs, H., and Ohbuchi, R. (1992). Merging virtual objects with the real world: Seeing ultrasound imagery within the patient. *Computer Graphics, 26*(2), 203 - 210.

Bransford, J., Sherwood, R. D., Hasselbring, T. S., Kinzer, C. K., and Williams, S. M. (1990). Anchored instruction: Why we need it and how technology can help. In D. Nix and R. Spiro (Eds.), *Cognition, education, and multimedia: Exploring ideas in high technology* (pp. 115 - 141). Hillsdale, NJ: Erlbaum.

Brehmer, B. (1995). Feedback delays in complex dynamic decision tasks. In P. Frensch and J. Funke (Eds.), *Complex problem solving: The European perspective,* (103-130); Hillsdale, N.J.: Lawrence Erlbaum Associates.

Bonk, C. J., and Dennen, V. P. (2005). *Massive multiplayer online gaming: A research framework for military education and training.* (Technical Report # 2005-1). Washington, DC: U.S. Department of Defense (DUSD/R): Advanced Distributed Learning (ADL) Initiative.

Bonk, C. J., and Graham, C. (Eds.). (in press). *Handbook of Blended Learning Environments.* New York: Jossey-Bass.

Brown, J. S., Collins, A., and Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32 - 42.

Caudell, T., and Mizell, D. (1992). Augmented reality: An application of heads-up display technology to manual manufacturing processes. In *Proceedings of Hawaii International Conference on System Sciences Vol II* (pp. 659 – 669). Los Angeles: IEEE Computer Society.

Duffy, T. M., and Cunningham, D. J. (1996). Constructivism: Implications for the design and delivery of instruction. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp 170 - 198). New York: Macmillan.

Feiner, S. (1992, May). *Annotating the real world with knowledge based graphics on a see-through head mounted display.* Paper presented at the Graphics Interface '92, Palo Alto, CA.

Feiner, S., MacIntyre, B., Hollerer, T., and Webster, T. (1997). A touring machine: Prototyping 3D mobile augmented reality systems for exploring the urban environment. *Personal Technology, 1*(4), 208 - 217.

Feiner, S., Webster, T., Krueger, T., MacIntyre, B., and Keller, E. (1995). Architectural anatomy. *Presence: Teleoperators and Virtual Environments, 4*(3), 318 - 325.

Fosnot, C. T. (1996) Constructivism: A psychological theory of learning. In C. T. Fosnot (Ed.), *Constructivism: Theory, perspectives, and practice* (8 – 33). New York: Teachers College Press.

Fowlkes, J., Dwyer, D. J., Oser, R. L., Salas, E. (1998). Event-based approach to training (EBAT). *The International Journal of Aviation Psychology,* 8(3), 209-222.

Gredler, M. (2004). Games and simulations and their relationships to learning. In D. Jonassen (Ed.), *Handbook of research on educational communications and technology* (pp. 813 - 828). Mahwah, NJ: Erlbaum.

Gunawardena, L. (2003). Theory into practice: The challenge in designing inquiry-based online learning environments. In T. Duffy & J. Kirkley (Eds.) *Learner centered theory and practice in distance education.* (235-249). Mahwah: NJ: Lawrence Erlbaum Associates.

Hollerer, T., Feiner, S., Terauchi, T., Rashid, G., and Hallaway, D. (1999). Exploring MARS: Developing indoor and outdoor user interfaces to a mobile augmented reality system. *Computers and Graphics, 23*(6), 779 - 785.

Hollerer, T., and Pavlik, J. (1999, October). *Situated documentaries: Embedding multimedia presentations in the real world.* Paper presented at International Symposium on Wireless Communications '99, Victoria, Canada.

Jonassen, D. (2000). Toward a design theory of problem solving. *Educational Technology: Research and Development,* 48(4), 63–85.

Kirkley, S., Borland, C., Pendleton, W., Waite, T., Turner, L., and Salaev, A. (2003). *Creating a global infrastructure for virtual aids to navigation (vAtoN) and information systems (vATONIS).* U. S. Coast Guard Research and Development Center Technical Report.

Kirkley, J., and Kirkley, S. (in press). Expanding the boundaries of blended learning. In C. Bonk and C. Graham (Eds.), *Handbook of Blended Learning Environments.* New York: Jossey-Bass.

Kirkley, J., Kirkley, S., Myers, T., Borland, C., Swan, M., Sherwood, D. and Singer, M. (2005). Embedded Training for Objective Force Warrior: Using Problem-Based Embedded Training (PBET) to Support Mixed and Virtual Reality Simulations. U. S. Army Research Institute for the Behavioral and Social Sciences Technical Report.

Kirkley, J., Kirkley, S., Myers, T., Lindsay, N., and Singer, M. (2003). Problem-based embedded training: An instructional methodology for embedded training using mixed and virtual reality technologies. In *Proceedings of the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC),* Orlando, FL.

Kirkley, J., Kirkley, S., Swan, M., Myers, T., Sherwood, D., and Singer, M. (2004). Developing an embedded scaffolding framework to support Problem-Based Embedded Training (PBET) using mixed and virtual reality simulations. In *Proceedings of the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC),* Orlando, FL.

Klopfer, E., Squire, K. & Jenkins, H. (2002). *Environmental Detectives:*PDAs as a window into a virtual simulated world. In the proceedings of the *International Workshop on Wireless and Mobile Technologies in Education.* Vaxjo, Sweden, 95-98.

Koster, R. (2004). *A theory of fun for game design.* Scottsdale, AZ: Paraglyph Press, Inc.

Leemkuil, H., de Jong, T., and Ootes, S. (2000). *Review of educational use of games and simulations.* EC project KITS (IST-1999-13078), KITS Deliverable D1, Enschede: KITS consortium.

Mayer, R. E. (2001). *Multimedia learning.* Cambridge, U.K.: Cambridge University Press.

Milgram, P., and Colquhoun, H. (1999). A taxonomy of real and virtual world display integration. In Y. O. H. Tamura (Ed.), *Mixed reality: Merging real and virtual worlds.* (5 - 30). Tokyo: Springer-Verlag.

Milgram, P., Takemura, H., Utsumi, A., and Kishino, F. (1994). Augmented reality: A class of displays on the reality-virtuality continuum. *SPIE, 2351,* 34.

Ong, S. K., and Nee, A. Y. C. (2004). Virtual reality and augmented reality

References for this article continue on page 89.

Kirkley -Continued from page 53

applications in manufacturing. Berlin: Springer-Verlag.
Piaget, J. (1932). *The moral judgment of the child.* London: Routledge and Kegan Paul.
Resnick, L. (1987). Learning in school and out. *Educational Researcher, 16*(9), 13 - 20.
Reigeluth, C. M. (1996, May-June). A new paradigm for ISD? *Educational Technology, 36*(3), 13 - 20.
Riesbeck, C., and Schank, R. (1989). *Inside case-based reasoning.* Mahwah: NJ: Erlbaum.
Savery, J. and Duffy, T. M. (1996). Problem-Based learning: An instructional model and its constructivist framework. In B. Wilson (Ed.), *Constructivist learning environments: Case studies in instructional design* (pp. 135 - 148). Englewood Cliffs, NJ: Educational Technology Publications.
Spiro, R. J., Feltovich, P. J., Jacobson, M. J., and Coulson, R. L. (1992). Knowledge representation, content specification, and the development of skill in situation-specific knowledge assembly: Some constructivist issues as they relate to Cognitive Flexibility Theory and hypertext. In T. M. Duffy and D. J. Jonassen (Eds.), *Constructivism and the technology of instruction: A conversation* (pp. 57-75). Mahwah, NJ: Erlbaum.
Sterman, J.D. (2000). *Business dynamics: Systems thinking and modeling for a complex world.* McGraw-Hill/Irwin.
Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*, 257 - 285.
van den Bosch, K. and Riemersma, J. B. J. (2004). Reflections on scenario-based training in tactical command. In S. Shifflett, L. Elliott, E. Salas, and M. Coovert (Eds.), *Scaled Worlds: Development, validation and applications* (pp. 1 - 21). Burlington, VT: Ashgate Publishing.
von Glasersfeld, E. (1995). *Radical constructivism: A way of knowing and learning.* London: The Falmer Press.

Kim -Continued from page 63

Seppälä, P. & Alamäki, H. (2003). Mobile learning in teacher training. *Journal of Computer Assisted Learning, 19(3), 330-335.*
Smith, R. A. & Anderson, L. K. (1994). Connecting the home, school, and community: Laptop computers. *Computing Teacher, 21*, 24-25.
South East Initiatives Regional Technology in Education Consortium (SEIRTEC). (2002). *Using Handheld Technologies in Schools, 5*(2), 1-34.
The National Centre for Technology in Education (n.d.). *Advice Sheets: Mobile phone.* Retrieved April 12, 2005, from http://www.ncte.ie/ICTAdviceSupport/AdviceSheets/MobilePhones/Page2/
The U.S. Department of Education (Sep. 2004). *Educational Technology Fact Sheet.* Retrieved April 4, 2005 from http://www.ed.gov/about/offices/list/os/technology/facts.html
The Wireless Foundation (April, 2005). *ClassLink: Results from schools.* Retrieved April 12, 2005, from http://www.wirelessfoundation.org/ClassLink/ActualResults.cfm
Trifonova, A. (2003). *Mobile learning--Review of the literature* (Tech. Rep. No. DIT-03-009). Italy, 38050 Povo-Trento, University of Trento, Department of Information and Communication Technology.
Vahey, P., & Crawford, V. (2002). *PalmTM Education Pioneers Program: Final evaluation report.* SRI International, Menlo Park, CA.
Yuen, S. & Yuen, P. K. (2003). PDAs as educational power tools. *Tech Directions, 62*(9), 14-17.