The Future of Digital Game-Based Learning

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ABSTRACT

This chapter discusses the potential future of games for learning through the lens of current advantages of real-world education that are thus far lacking in educational games. It focuses on four main facets of the real-world educational experience: adapting content to an individual student, the rigorous evaluation of educational media, the ease of modification of educational games, and the application of games to new domains and teaching techniques. The chapter then suggests how we as designers and developers can make strides towards incorporating these lacking elements into how we build and use educational games. The author hopes that this discussion can be used to foster discussion about where the field could be and should be going in the near future.

INTRODUCTION

Here we are at the edge of the frontier. The serious games movement has gained momentum by leaps and bounds in the past decade. The Serious Games Initiative has helped foster a community of academics and industry designers interested in combining game design with educational techniques to create digital game-based learning experiences. New school curriculums have been funded by the MacArthur Foundation that focus heavily on employing games for learning (Barab, et al. in press; Chaplin 2007). We are coming into our own as a community as games for learning gain slow acceptance from funding agencies, the education community, and the general public. As we learn more about how to build educational games that are well designed, we should also reflect on the current state of affairs and ask ourselves, "What is missing?" or more specifically, "What aspects of proven real-world educational experiences are we currently lacking in educational games?" Once we come to some answers to this question, we then finally need to ask, "What can we do about it in the future to maximize the potential of games as a medium for learning?"

The first aspect of real-world education missing in educational games thus far is *individualized adaptation* to focus a digital game-based learning experience on a particular student's needs. Students in a traditional classroom have varied learning styles that require different teaching techniques for them to effectively comprehend the material (Felder and Silverman 1988; Riding and Sadler-Smith 1997) (e.g. presenting a physics lesson in lecture by giving the formula and examples, then going into the lab and letting students physically play around with the principles covered). Educational games are typically not designed to attack a learning problem in this kind of multi-dimensional model. They are instead designed as a typical entertainment game is, aiming for a single design for a rough population of users (e.g. 10th -12th graders).

In an ideal learning situation, students get their individual needs met in small classrooms or one-on-one teaching or tutoring sessions. Students perform significantly better when given this kind of attention compared to general classroom learning alone (Cohen, Kulik and Kulik 1982; Bloom 1984). The educational games community has started to look at how intelligent tutoring system (ITS) technology, which provides some of the positive results of real-life human tutoring, can be employed to monitor student aptitude in a game and select material to address learning needs (Gomez-Martin, Gomez-Martin, and Gonzalez-Calero 2004; Johnson, Vilhjálmsson, and

Marsella 2005; Van Eck in press). The defining feature of an ITS is that it carefully oversees a learner's work on problems to provide needed guidance and content selection. An ITS models the actions and interventions of a human tutor, which is the most effective means of instruction (Bloom 1984). ITSs identify the need for instructional interventions by comparing a model of expert performance with a model of the learner's performance (Koedinger, et al. 1997). ITSs traditionally employ a *model trace*, which is a fine-grained cognitive model designed to identify what strategies a student is employing to solve a problem. When the student is having trouble arriving at the correct answer, the systems can use the model trace to identify specifically what is wrong with the strategy being employed and what istudent proficiency in the various topics being taught and select content to address student deficiencies in that content.

We as researchers have taken the initial steps to identify the need of individualized teaching in games and a usable technology that can help address that need. Games have already employed intelligent tutoring systems to teach such topics as language (Johnson, Vilhjálmsson, and Marsella 2005), computer programming (Gomez-Martin, Gomez-Martin, and Gonzalez-Calero 2004), and interpersonal and intercultural skills (Lane, et al. 2007). However, is the traditional ITS model of providing individualized guidance and selecting content as far as we can go? Educational games can expose the student to educational content in both a declarative manner (i.e. presenting text or graphics that communicate some learning concept), as ITS systems typically do, and a procedural manner (i.e. through the act of employing game mechanics to change the game world in some meaningful way). There is a rich future in exploring how we can take advantage of adapting both the declarative and procedural content of games to provide a game experience that is tailored to an individual's needs along a series of dimensions, not just the typical ITS adaptation of declarative content.

The second aspect of real-world education to address is the benefits of public acceptance of teaching techniques and methods for classroom instruction. Lectures, workbooks, reading and writing assignments, roleplay exercises, etc. all are generally accepted parts of training exercises and classroom education. Using computer games is still on the fringe in terms of public acceptance and more importantly in terms of broad integration with classroom and training curricula. Gaining broader acceptance is a desirable goal we must reach in order to maximize the potential and use of games for learning.

Intelligent tutoring systems, such as the algebra tutors from Carnegie Mellon University, are examples of digital-based learning that have found their way into classrooms, industry training systems, and military applications (Koedinger, et al. 1997). The main reason this approach has had success is that they have successfully proven the techniques of model and knowledge tracing through both rigorous lab experimentation as well as through case studies in classroom environments. Simply put, they have shown that students learn better with their technology. We as a community seem to put much more focus on the fact that our creations *exist* compared to showing how incredibly useful what we have created is. Piecemeal evaluations of some games are done, but we have yet to cross that threshold into broad use by showing with large scale evaluations that games / designs / technologies can guarantee improvements in student learning.

Third, part of integrating with classrooms and other forms of education is how easily educators can adapt / modify / instantiate technologies to fit their classroom's needs. A typical educational game that is built is typically standalone. If someone wants to modify it, they go back to the game company, if at all. User-created content is rarely a function of the design. Unlike the entertainment industry, the educational game industry rarely supports "mod communities" or authoring tools for educators to create or augment games they use. There are some counter examples, such as MIT's *Scratch* (Peppler and Kafai 2007) or the Scribe authoring tool (discussed below) that accompanies the Interactive Story Architecture for Training (ISAT) (Medler and Magerko 2006). However, these examples are easily in the minority. In order for educational games to gain wide usage, putting authorship into the hands of the students and educators using the technology seems imperative.

Finally, the last aspect of education in the real-world that has yet to transfer into the realm of educational games is the plethora of learning domains that have yet gone untouched. Digital games are not used to teach good acting skills, jazz improvisation, or how to analyze fiction – why? Is the barrier that these kinds of games are simply more difficult to design? Are there technological barriers to creating certain kinds of games that make it currently impossible to do them well or at all? Are educational games just not suitable for these and other domains? Games are good at involving students in a procedural experience that they learn from. Is the problem that we don't understand the process of some domains (e.g. jazz improvisation) well enough to appropriately model them on the computer? Understanding the answers to these questions will go a long way to understanding just how far reaching the potential of this educational medium is.

Along with identifying new domains for games, we can also focus on *using games* in different ways for teaching, such as building games – as opposed to playing them – as an educational exercise. For example, Grade 10 students in Alberta have used Neverwinter Nights for learning the basics of writing stories (Carbonaro, et al. 2005). Students in Austria have used building games to research many topics, from the fine arts to medicine (Pivec and Kearney 2007). The Global Kids organization had involved urban youth in building games to learn about issues with poverty (Ua'Siaghail and Joseph 2006). Building games inherently teaches good teamwork skills, technology literacy, brainstorming skills, and time management. These skills alone are important for students to have as they enter the workforce or go on to advanced degrees in their studies. Beyond the intrinsic lessons of building games, games are potentially a positive and engaging medium for representing models on various topics of study. The intergration of games in many different courses of study seems likely to be a big part of the future of games for learning.

HOW CAN WE GET THERE?

Adaptation

Good design and the smart use of artificial intelligence techniques, such as using intelligent tutoring techniques for guidance and selection of content, are essential to providing game experiences that provide an individualized experience for a student. The key concept to consider is that while intelligent tutoring systems only adapt declarative knowledge in an educational experience (e.g. tutoring guidance or selected lessons) for certain kinds of domains, *educational games can adapt the procedural content as well as the declarative content.*

Game players literally learn by playing the game (Gee 2003). The mechanics of a game afford how the player can affect the game world (e.g. jumping across difficult chasms, shooting numbers with a blaster, or aiming a virtual fire hose at the right location to quell a raging fire). If different people learn in different ways and like to play games for different reasons (Bartle 1996), why not *adapt the actual mechanics of the game* as well as the declarative content to provide an experience that suits a particular student? Games have the enticing potential to identify key characteristics of the student that directly relate to the learning effectiveness of the gaming experience, such as: student knowledge (e.g. model and knowledge tracing), which is already used in some systems; the student's learning style (Carver, Howard, and Lane 1999); the student's play style; social interactions with non-player characters (NPCs) and other human players; and the student's involvement as a character in a dramatic experience.

The following sections describe two prototype systems in different stages of early development that adapt to player input in an attempt to tailor the learning experience. The first system, *S.C.R.U.B.*, adapts game content based on player learning style and play style. The second, the Interactive Story Architecture for Training (ISAT), places the player in a dramatic scenario that provides in-game feedback and selects, adapts, and refines story content based on both the player's dramatic and pedagogical need.

S.C.R.U.B.

As part of a collaboration between the Experimental Game Lab (EGL) at the Georgia Institute of Technology and the Games for Entertainment and Learning (GEL) Lab at Michigan State University, we are currently developing a prototype game called *S.C.R.U.B.* (Super Covert Removal of Unwanted Bacteria), an exemplar adaptive digital game-based learning experience that teaches about antibacterial resistant microbe evolution and transmission set within a hospital.

S.C.R.U.B. is designed to be a collection of mini-games that address different facets of microbe evolution and transmission, such as how hand washing with different materials affects microbes on the hands, how microbes can quickly adapt to antibiotics used incorrectly, and how microbes can easily transfer from surface to surface through physical contact. Figure 1 is a screenshot from the first mini-game under development, which teaches about hand washing techniques by giving students the opportunity to see what happens when soap is applied to the skin at the microscopic level. Students can select soap, anti-bacterial soap, or alcohol-based cleanser to "shoot" at the microbes. The different effects of each are visualized (e.g. normal soap "sticks" to microbes until they are washed away and "sticks" to water molecules to be washed away).

*S.C.R.U.B.*s main research foci are:

a) The creation of a game that can adapt during play to become an ideal educational game experience for different student learning and playing styles. This addresses a principle already well known in the education community: not everyone learns the same way. The "one way to teach fits all" strategy to education suits the constraints of a classroom with 30 students, but it fails to meet the needs of every student (Cohen, Kulik, and Kulik 1982; Bloom 1984). The philosophy behind *S.C.R.U.B.*s design is that people learn and play in different ways. Games can recognize and accommodate these differences. Mini-games are both selected and adapted to these differences.

b) The dynamic identification of student learning style and play style during play to let the game know how to optimize the experience for each individual player-learner. Our current work addresses four player-learner styles, derived from reviews of the literature on learning styles and play styles (Kolb 1984; Bartle 1996). Individuals are classified along two axes – motivation

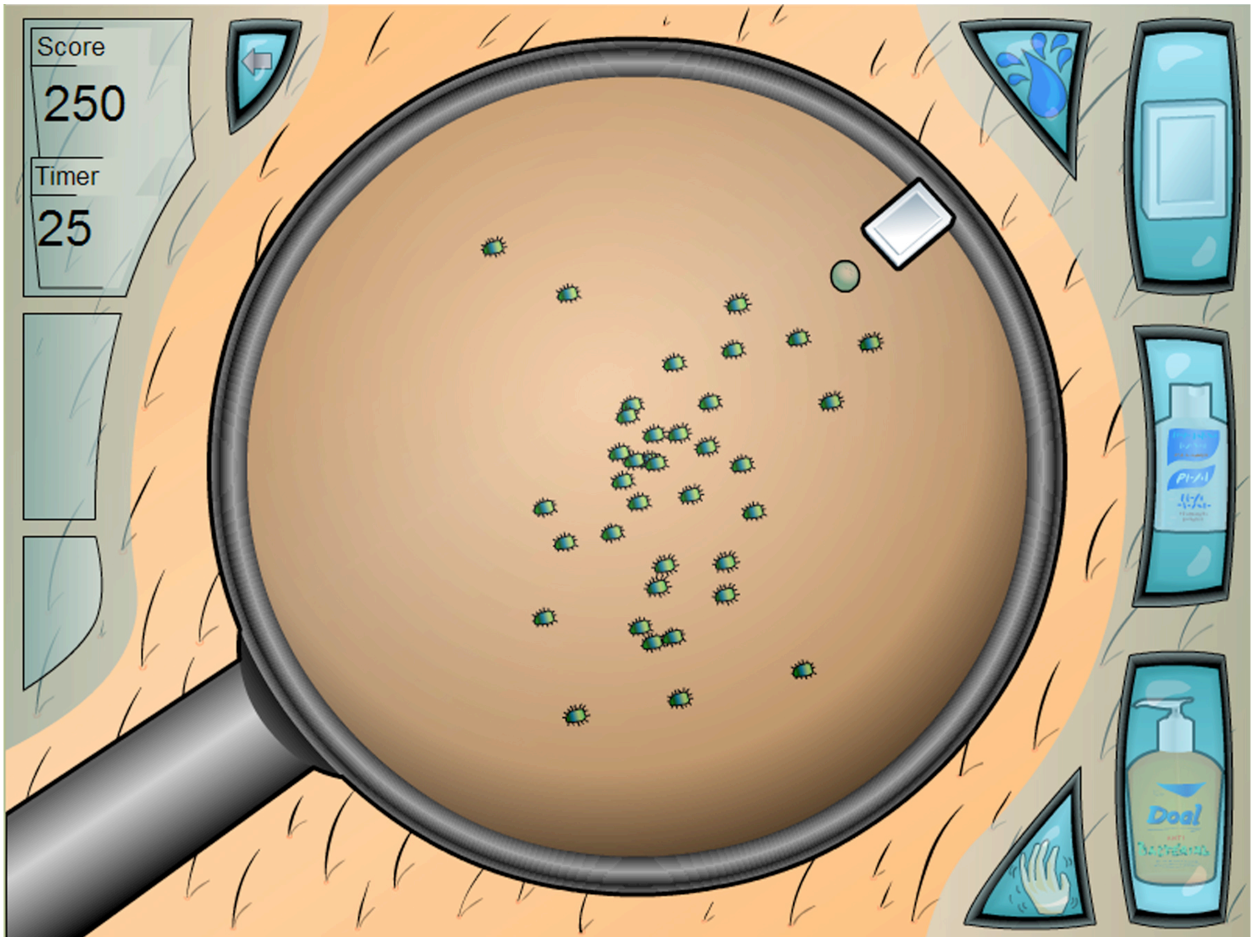

Figure 1. Screenshot from *S.C.R.U.B.* mini-game.

(intrinsic versus extrinsic) and cognition (reflective versus active). Each quadrant has significant implications for preferred learning and play style in a game.

c) The design of the educational game itself, which is a significant contribution to the growing body of design research in serious games. We are exploring how to appropriately represent the interactions in the microbial domain that severely impact human and societal health. We seek to convey these intersecting domains in a manner that vividly and effectively communicates the processes of how MRSA (methicillin-resistant *Staphylococcus aureus*) becomes resistant, how it is transmitted, and steps to prevent transmission. This challenge brings together art, science, medicine, game design, and learner cognition. Solutions will inspire and inform other science games that need to incorporate micro and macro interactions.

The current hand washing mini-game employs exemplar adaptations that reflect the general design and intent of *S.C.R.U.B.* Students are identified in a pre-test as one of four different learning types based on dimensions identified in Kolb's research on student learning styles. Those learning styles are also mapped to the relevant Bartle play styles (1996). Both models were selected for their ease of use and broad acceptance in their respective communities. Students are identified in the *processing dimension* along a spectrum of how *active* or *reflective* they are in regards to preferring active experimentation or reflective observation. In the

	Extrinsic (Achiever)	**Intrinsic (Explorer)**

Reflective	- **Use tutorial** (player would like to see what is coming and have time to prepare) - **Unlimited Resources** (though this player is fueled by extrinsic values, the need to acquire resources may hinder their ability to reflect on how and why resources work in different situations.) - **Static UI** (the player is mainly fueled by achievements, which score and time are key, and so would have no need to get rid of them.) - **Score** (part of Static UI) - **Timer** (part of Static UI) - **Pause button** (to allow the player to pause and reflect on the situation) - **Buffs (Score based)** (part of achieving, while they have unlimited resources, getting extra points or abilities are still achievements) - **Information stops game play** (for reflection, they want to have time to see the content) - **Receive points for information gathering** (while they may want to reflect on the content they would also like to receive some achievement for how much content they have experienced) - **Levels - provide content and points** (levels in the game give an educational value, how different layers of the skin react to washing)	- **Use tutorial** (player would like to see what is coming and have time to prepare) - **Unlimited resources** (the need to acquire resources will hinder their ability to reflect on how and why resources work in different situations.) - **Modifiable UI** (to view score) (does not need to see score or time to enjoy the game, but may choose to, for exploring purposes) - **Pause button** (to allow the player to pause and reflect on the situation) - **Buffs (Unique abilities)** (part of exploring, they want to find new abilities that they can use to find and make sense of content) - **Information stops game play** (for reflection, they want to have time to see the content) - **Ability to watch game instead** (they are not fueled by achieving, or actively participating in the game, and wish to learn the information and have time to figure problems out on their own. - **Levels provide content** (levels in the game give an educational value, how different layers of the skin react to washing)
Active	- **No tutorial** (players wish to jump right in, they want to learn by doing not by being told) - **Limited resources** (they need to achieve and be active in their performance, so they need to be challenged on how they manage their resources) - **Static UI** (the player is mainly fueled by achievements, which score and time are key, and so would have no need to get rid of them.) - **Score** (part of Static UI) - **Timer** (part of Static UI) - **Buffs (Score based)** (part of achieving, while they have unlimited resources, getting extra points or abilities are still achievements) - **Information separate from game play** (they do not necessarily care too much about finding learning content and just wish to experience the game. The content is placed elsewhere for them to access.) - **Levels provide points** (levels are seen as achievements, higher level means the player feels they are doing better)	- **No tutorial** (players wish to jump right in, they want to learn by doing not by being told) - **Unlimited resources** (the need to acquire resources will hinder their ability to explore how and why resources work in different situations.) - **Modifiable UI (to view score)** (does not need to see score or time to enjoy the game, but may choose too, for exploring purposes) - **Buffs (Unique abilities)** (part of exploring, they want to find new abilities that they can use to find and make sense of content) - **Information available during game play (play continues)** (they are interested in learning the content but want to experience on their own terms and not have it pushed on them) - **Levels provide content** (levels in the game give an educational value, how different layers of the skin react to washing)

Table 1. Initial mapping of hand washing adaptations to player learning style.

motivation dimension, they are identified as to how much they seek *extrinsic* rewards (e.g. getting an item in a game) vs. *intrinsic* rewards (e.g. satisfaction from exploring a game world).

The concept of extrinsic and intrinsic learners maps very closely with Bartle's player types of "achievers" (players who try to accomplish concrete goals set up by the game) and "explorers" (players who get fulfillment from exploring the details and boundaries of the game world). Game content and mechanics are then selected based on which combination of styles (e.g. Reflective-Intrinsic) best suits them.

Table 1 displays the current mapping (which is subject to change based on play testing) being employed in the hand washing mini-game. For example, Intrinsic-Active learners prefer to actively experiment for the sake of internal rewards (i.e. explore for the sake of learning as opposed to the goal of getting a high score). Therefore, informational pop-ups that convey related facts to microbe transmission are available during gameplay while play continues. They are given the chance to absorb information in real-time (as opposed to stopping and reviewing / reflecting on information) and to learn within the gaming experience as opposed to separately.

This adaptation of game mechanics and content directly reflects the hypothesis that games can mirror the kinds of pedagogical adaptations seen in real-life teaching situations beyond the traditional ITS model. Future iterations of the design and development will map learning styles and playstyle preferences together to address both how students learn best and how they like playing. We will conduct evaluations of this hypothesis with the initial hand washing mini-game in the near future, once the prototype is mature and thoroughly playtested.

The Interactive Story Architecture for Training (ISAT)

The field of interactive story (also called "interactive drama" or "interactive narrative") attempts to provide dramatic experiences typically that involve the player as a main character in an unfolding story within a game world. Per Chris Crawford's definition of interactivity, an interactive story system observes player inputs (e.g. flirting with an NPC, grabbing an important item, or yelling incoherently in a public market), thinks about how to respond (e.g. flirting back with the character), and performs an action in response. (Crawford 2004). Mateas and Stern's *Façade* (2003) is an oft-cited work that is arguably the first if not the most polished full-fledged interactive story experience. New systems have begun to integrate techniques in interactive story into approaches to training, such as employing a "drama manager" intelligent agent to coordinate the behavior of NPCs in response to both player actions and pre-authored or generated story content (Magerko, Stensrud, and Holt 2006; Riedl and Stern 2006).

While it is still unclear whether or not interactive story is a viable medium for entertainment, it is much clearer how the problems addressed in the field are similar to those seen in interactive training. Both are concerned with presenting an interactive experience to the player in a virtual world. Both have author-specified content that the system presents to the player. Both have a tension between interactivity and authorship – that is, the player wants to have control in how the story develops, as does the author of the story or learning scenario. However, in interactive story, the primary goal is providing an engaging experience to the player (having fun) while in interactive training the main goal is usually having the student learn how to apply some knowledge or demonstrate a skill. "Fun" may be a goal (if a learning experience is enjoyable the student is likely to participate enthusiastically and frequently) but is usually subsidiary to the learning goal.

There is not only story (or scenario) content that is authored and given as an input to the system, but there is the additional constraint to be sure that the player *experiences that content*, while still providing an interactive experience. The implication of this desire is that there is a weaker, though still existent, connection between player choice and the resulting experience. In an interactive story system, we can imagine a boundless world, where a vast amount of novel and interesting stories is possible based on the choices we make. In contrast, an interactive trainer is built to teach a particular set of principles, skills, or information. These requirements bias the experience to lean towards making sure the desired skills / knowledge / etc. is taught and / or tested.

The Interactive Story Architecture for Training (ISAT) is an approach to training that combines aspects of intelligent tutoring systems and interactive story to provide a learning experience that adapts content based on both pedagogical and dramatic concepts. ISAT employs an intelligent director (or drama manager) that coordinates the behaviors of the NPCs (i.e. gives them new goals to fulfill or actions to execute) based on a pre-authored learning scenario and the actions that the student executes in the environment. ISAT is currently instantiated in a combat medic trainer (called the Tactical Combat Care Trainer) (Magerko, Stensrud, and Holt 2006) but is designed to be appropriate for process-based learning content where students learn how to select and execute appropriate actions in the real world (as opposed to more abstract learning topics, such as physics or programming).

The director takes pre-authored scenario as an input from a human trainer that details the story content and the skills taught / tested within that content. The player is allowed to move through the story as they wish. If they go off path of what has been scripted, the director alters the story world to try and bring the player "back on course" (e.g. having the staff sergeant yell "Hey, we need a medic over to stay with his squad. Get over here!"). If the student is having particular difficulty with the learning content, the director employs in-environment scaffolding and fading effects through directing NPC behaviors. For example, if the trainee has just started learning how to be a medic and doesn't show aptitude in how to prioritize which casualties to aid first, the director may give heavy-handed feedback from a nearby soldier ("Go treat the burn victim first! What are you doing??"). As the trainee gains proficiency, the aid fades in severity (e.g. the burn victim only yells loudly to get the trainee's attention as opposed to the trainee being directly told to treat the burn victim).

The director also selects which authored story events (called plot points) should happen next based on both what skills they address and what the director's skill model of the player reflects in terms of teaching needs. For example, if the trainee is particularly bad at applying tourniquets, a plot point may be selected that creates a situation where tourniquets are needed (e.g. an explosion in a courtyard). Selection of plot points is also based on dramatic relevance – more "tense" plot points are chosen as the experience moves to or away from a climax. The director is also designed to fill in the details of plot points to reflect the specific dramatic choices a student has taken, but instantiation of plot content has yet to be developed.

ISAT provides an adaptive experience that alters both narrative and pedagogical guidance based on its model of the student. *S.C.R.U.B.* alters what mini-games are selected and how they work depended on a model of the player's play and learning preferences. These systems are prototype exemplars that hint at the promise of how intelligent game adaptation can help define the effectiveness and quality of engagement of educational games of the future.

Evaluation

The single most important thing that we as a community can do to broaden the acceptance and usage of digital game-based education is to work with educational systems, both in terms of schools and industries, to perform rigorous evaluations of our games in classrooms where the proverbial rubber hits the road. Evaluations like these will improve the overall quality of work in our field as well as encourage a shift in public perception of the potential of games as an educational medium. The medical and military domains have already taken the first step in this regard, employing games in training facilities and military installations.

The catch, of course, of doing such evaluations is that there is a fuzzy line between evaluating games as an approach and evaluating the quality of games. Using game technology does not instantly equal a good learning experience. The fuzzy arts of game design and educational design make it difficult to make broad claims about an approach. In contrast, intelligent tutoring systems have well-defined processes for building their components – they are much more technology-driven (e.g. building an accurate student and expert models or new approaches to intelligent guidance) than design-driven and therefore easier to evaluate.

This is all the more reason for us to focus compulsively on evaluating the games we build and not easily accepting games that have not been evaluated. Educators / psychologists / trainers do not typically adopt teaching methods en masse without firm theoretical and experimental foundations; they tend to use what they know works. Our community can be equally as particular if we decide to be. For example, the prototype systems mentioned earlier, *S.C.R.U.B.* and ISAT should not be considered successes until they are experimentally show to work. If we focus on not only the production of systems, but the quality evaluation of those systems, we are only doing ourselves a favor in terms of showing us and outsiders what works and what does not. Show that our games are "engaging" and effective, and educational games will have an even stronger story to tell.

Authoring Tools

As mentioned earlier, languages and environments, such as Scratch and Alice, have been developed to make it easier for non-programming students and educators to make (normally fairly simple) games. However, the field has focused far less on making educational games modifiable for educators and students alike. In conjunction with the points made earlier about the future of educational games, authoring tools for educational games may make a significant impact on their adoption and ease of use in traditional educational settings.

The advancement of educational games in terms of authoring tools requires the forward thinking to develop authoring environments that do not require programming skills to create / edit game content. For example, the ScriptEase authoring tool developed at the University of Alberta (Carbonaro, et al. 2005) allows users who have never created a game before to create a Neverwinter Nights plot solely by using a menu-driven experience. Though not specifically for an educational serious game, the design of this is tool is an important lesson in usability for non-programmer users.

A more relevant example to the educational game domain is the Scribe authoring tool created for ISAT (Medler and Magerko 2006). Scribe is a tool that is designed specifically for trainers to be able to encode training scenario content for an ISAT-controlled interactive story. Given the same game world, art assets, etc., an educator can use Scribe to encode varied training scenarios that teach / test the specific principles that they wish. Scribe has three editing modes: element placement mode, story creation, and debugging. *Element placement mode* (as shown in Figure 2) offers the user a 2.5D representation of the physical environment. The user can instantiate the different physical elements used in the scenario (e.g. characters, objects, spawn points, and "zones" that describe regions) and edit their properties. This authoring mode acts as a "virtual dollhouse" where the user can configure the world and then use *story creation mode* to capture the dollhouse's configuration as conditions and actions for an event that is to occur in the scenario. *Debugging mode*, which is still in design, is intended to give the user an opportunity to rapidly play through the story and director actions without working directly in the game environment. The ISAT director is connected to Scribe and then queried with various game world configurations to see a) what the director would do in that situation and b) if the story plays out as intended by the user.

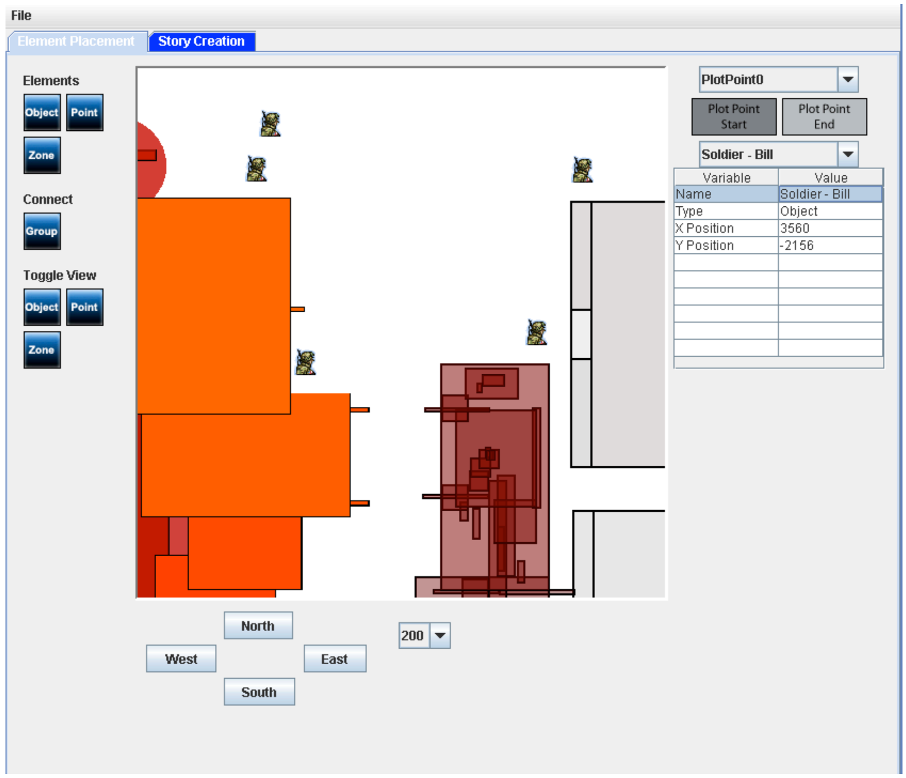

Figure 2. Element placement mode screenshot from Scribe.

This tool allows an educator with no programming background to visually author new content for an interactive training environment shipped with the ISAT architecture. The intention of this design is to avoid the back and forth between subject matter experts (or educators) and developers that can take place when scenarios need to be developed or modified. The addition of these kinds of tools to educational games, though expensive to include, may increase the longevity and usefulness of the games that we create. Mod communities in the entertainment game realm give us an extreme example of what is possible if you allow users to modify the games that we create. For example, a mod community first developed the wildly popular game *CounterStrike* (Cliffe and Le 1999), which has its current incarnation now shipped by Valve with the game *Half-Life 2* (Valve 2004).

Accessibility in New Domains

There are plenty of domains that have yet to be explored in the context of digital game-based education. For example, games rarely exist – if at all – that teach in domains that involve complex audio input (e.g. music performance or speech), video input (e.g. sign language or karate), or semantic reasoning (e.g. music composition or rhetoric). If computers are typically bad at interpreting these kinds of inputs (i.e. visual, audio, and semantic input), how can we as designers expect to branch into new fields that depend on them?

One answer is that we can put the "hard stuff" onto other human players or interactors. For example, the Ink project uses an online game as a means of connecting students with guides at the Michigan State University Writing Center (Buchanan 2006). One can imagine using that metaphor for other difficult domains, such as a jazz piano improvisation game. A game could give students the ability to alternate playing solos and rhythm parts in a big band piece while using microphone or MIDI inputs or alternatively creating a Web site where solos are posted and students vote on each other's performances and vie for superior ratings from their peers and educators. The creative incorporation of other human players in a game setting may make a difficult problem, such as the comprehension and analysis of a piece of writing, doable.

Another approach to handling hard domains is to collaborate with ongoing artificial intelligence research to attempt to adequately solve some of these problems. For example, there is no doubt that we will in the not-so-distant future have games that take full-body motion video as inputs to fighting games, sports games, and the like. Daringly pushing the envelope with current advances in technology (e.g. the natural language processing done by *Façade* (Mateas and Stern 2003)) can lead to innovative new forms of gameplay that, though not perfect, provide us with novel and useful educational (and entertaining) experiences.

As opposed to only focusing on the technology issues with educational games, we can also discuss *how games are used* for teaching as opposed to simply as a learning experience by playing games. As Marc Prensky points out, educators have used games in observational exercises to encourage verbal and writing skills, to teach concepts about story construction, and concepts about historical processes (Prensky 2006). Games are uniquely apt at representing models of processes (e.g. economies, warfare, daily tasks in a household, etc.). The act of building games itself can be a valuable learning tool. In order to build a model of something in a game, such as an economic structure, a planned urban area, or a military strategy, the person building it has to understand that model. Building a game to learn a particular concept, using engines / languages like Alice (Conway, et al. 2000), Scratch (Peppler and Kafai 2007), or Processing (Reas and Frye 2007) or employing off-the-shelf games not originally intended for education (e.g. the Civilization series (Squire 2005)) that are designed for easily prototyping games, has the potential to be a fun, engaging, and useful tool for educators that may become far more used. The development and adoption of engines and languages such as these is incredibly important to the use of game design and development as a learning exercise. Students need to be able to work on the core concept they are trying to model, such as microeconomics theory, without worrying about the details that go into the development of a commercial game (which hearkens back to our need for authoring tools for educators as well as students).

IMPLICATIONS

This chapter discusses one person's musings on where our field has the potential to go. These directions are intended to be grounded in current research directions, such as adaptation or authoring tools, but they point to the need for a larger community effort to adopt these techniques / efforts in order for us to better realize the potential of this exciting medium. What we as individuals in the community can do is the single most import takeaway from this discussion.

The bottom line from the example systems discussed in the adaptation section is that, in order for a system or teacher to provide individualized feedback / content / adaptation of content, a model of the student is key. The "one-size fits all" approach to digital game-based learning is only a first step in using the medium. Unlike previous educational media advances, games have to potential to adapt to students in the same way human teachers do, providing a powerful advantage over other non-computational approaches. Even a well-designed shallow model of the student, such as their learning style, can give the system an enormous advantage in teaching the student.

The intention of discussing the importance of evaluation is simple – the more pervasive evaluations of our games and technique are, the more credibility and broad acceptance the field will have. That is not to say that games are not being evaluated. However, we have yet to reach the critical point of *expecting* evaluations, as opposed to simply marveling at a) what seems like a good idea, b) actually got built, and c) has sexy graphics (all too common of a pitfall in educational and entertainment games). Getting there as a community will only benefit us in terms of the quality of our creative output as well as acceptance.

The development of authoring tools for educators may seem like an unwanted or unnecessary addition to some game projects. However, if we want educators to use our games (as opposed to solely placing them on Web sites for the general public to discover), we need to make them as usable as possible. This means thinking about a) who is going to use it (e.g. high school history teachers), b) what kind of changes they may want to make (e.g. do they need a tool for scripting characters and dialogue, like ScriptEase or Scribe? Do they need to be able to import and manage 2D images? Add quiz questions?), and c) how to make that happen without necessarily relying on conventional game development knowledge (e.g. scripting or programming, 3D level editing, etc.).

A focus on accessibility in new domains and the exercise of building games as a learning exercise may be the most Pollyannaish desire to consider here. Exactly what domains games are / are not good at teaching in really has not been fleshed out yet. It could be that a good jazz improvisation game using digital games is simply a terrible idea, all technology issues aside. However, we simply will not know unless we take the initiative to push into new domains that may have imperfect or creative solutions to teaching in them. Designers can consider how to incorporate humans in pedagogical, cooperative, or competing roles to make up for reasoning that computers are poor at. Conversely, games can collaborate with artificial intelligence researchers and adopt new techniques that work well enough to create a completely new game experience. The exercise of creating games as a learning experience itself is a creative way at looking at how games can be used in an educational setting. Considering what model you want students to learn and how you want them to learn it (e.g. exploring possibilities within a model by building a game based on it vs. understanding how to behave within it by playing a game based on it) is intrinsic to identifying the best application of games in an educational setting.

Educational games have enormous unfulfilled potential. With creative thinking to consider how games can best serve both students and educators in terms of their educational needs, the games they wish to create and play, and the domains they wish to explore, the future of digital game-based learning looks bright. The issues that we are considering five, twenty, and fifty years into the future will hopefully represent healthy progress for the medium and our community at large.

REFERENCES

Bartle, R. (1996). "Hearts, Clubs, Diamonds, Spades: Players Who Suit MUDs."

Barab, S., Dodge, T., Tuzun, H., Job-Sluder, K., Jackson, C., Arici, A., Job-Sluder, L., Carteaux, R., Jr., Gilbertson, J., and Heiselt, C. (in press). The Quest Atlantis Project: A socially-responsive play space for learning. In B. E. Shelton & D. Wiley (Eds.), *The Educational Design and Use of Simulation Computer Games*. Rotterdam, The Netherlands: Sense Publishers.

Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13(6),* 4-16.

Buchanan, K. (2006). Beyond Attention-Getters: Designing for Deep Engagement. Ph.D. Dissertation for the Department of Counseling, Educational Psychology and Special Education, Michigan State University.

Carbonaro, M., Cutumisu, M., McNaughton, M., Onuczko, C., Roy, T., Schaeffer, J., Szafron, D., Gillis, S., and Kratchmer, S. (2005). In Proceedings of 2nd Digital Games Research Conference (DiGRA 2005), Vancouver, Canada.

Carver, C.A., Jr.; Howard, R.A.; Lane, W.D. (1999). Enhancing student learning through hypermedia courseware and incorporation of student learning styles. *IEEE Transactions on Education*, vol.42, no.1, pp.33-38.

Chaplin, H. (2007). Proposed Video-Game School Gets $1.1 Million Boost. National Public Radio. Retrieved on 10/31/2007 from http://www.npr.org/templates/story/story.php?storyId=11259040.

Cohen, E.G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research*, 64(1), 1-35.

Cohen, P. A., Kulik, J. A., & Kulik, C. C. (1982). Educational outcomes of tutoring: A meta-analysis of findings. *American Educational Research Journal*, 19, 237-248.

Conway, M., Audia, S., Burnette, T., Cosgrove, D., and Christiansen, K. (2000). Alice: Lessons Learned From Building a 3D System For Novices. *Proceedings on CHI: Human Factors in Computing Systems*, The Hague, The Netherlands, Apr 1-6, 486-493.

Cliffe, J. and Le, M. (1999). *CounterStrike*.

Crawford, C. (2004) *Chris Crawford on Interactive Storytelling*. New Riders Games, Berkeley, CA.

Felder, R.M. and Silverman, L.K. (1988). Learning and Teaching Styles in Engineering Education. *Engineering Education, 78* (7), 674.

Gee, J. P. (2003). *What Video Games Have to Teach Us about Learning and Literacy.* Palgrave Macmillan, New York.

Gomez-Martin, M., Gomez-Martin, P. and Gonzalez-Calero, P. (2004). Game-driven intelligent tutoring systems. In *Proceedings of the Third International Conference on Entertainment Computing (ICEC)*, pages 108–113.

Lane, H.C., Core, M.G., Gomboc, D., Karnavat, A., and Rosenberg, M. (2007). Intelligent Tutoring for Interpersonal and Intercultural Skills. In the *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC 2007)*, Orlando, FL.

Johnson, W.L., Vilhjálmsson, H., and Marsella, S. (2005). Serious games for language learning: How much game, how much AI? *Proc. of the* 12^{th} *Int. Conf. on AI in Education*.

Koedinger, K. R.; Anderson, J. R.; Hadley, W. H.; and Mark, M. A. (1997). Intelligent Tutoring Goes to School in the Big City. *Journal of Artificial Intelligence in Education* 8(1):30–43.

Kolb, D. (1984). *Experiential learning: Experience as the source of learning and development*. New Jersey: Prentice-Hall.

Magerko, B., Stensrud, B., and Holt, L. (2006). Bringing the Schoolhouse Inside the Box – A Tool for Engaging, Individualized Training. In the *Proceedings of 25th Army Science Conference*. Orlando, FL.

Mateas, M. and A. Stern (2003). Facade: An Experiment in Building a Fully-Realized Interactive Drama. *Game Developer's Conference*, San Francisco, CA.

Peppler, K. A. and Kafai, Y. B. (2007). What video game making can teach us about learning and literacy: Alternative pathways into participatory cultures. In *Proceeding of the Digital Games Research Association Conference (DIGRA 2007)*. Tokyo, Japan.

Pivec, M. and Kearney, P. (2007). Games for Learning and Learning from Games. In *Proceedings of Information Society*, 12 - 13th October 2007, Ljubljana Slovenia.

Prensky, M. (2006). Don't Bother Me Mom – I'm Learning! Paragon House, St. Paul, MN.

Reas, C. and Fry, B. (2007). Processing: A Programming Handbook for Visual Designers and Artists. MIT Press, Cambridge, MA.

Riding, R. J. and Sadler-Smith, E. (1997). Cognitive style and learning strategies: Some implications for training design. *International Journal of Training and Development*, *1*(3), 199–208.

Riedl, M. and Stern, A. (2006). Believable Agents and Intelligent Story Adaptation for Interactive Storytelling. *Proceedings of the 3rd International Conference on Technologies for Interactive Digital Storytelling and Entertainment*, Darmstadt, DE, 1-12.

Squire, K.D. (2005). Changing the game: What Happens When Videogames Enter the Classroom?. *Innovate 1(6)*.

Ua'Siaghai, A. and Joseph, B. (2006). Reaching New Audiences and Distribution Channels around the K-12 Education System. Panel Discussion at *Games for Change Conference*, New York.

Valve. (2004). *Half-Life 2*.

Van Eck, R. (in press). Building Intelligent Learning Games. In David Gibson, Clark Aldrich, & Marc Prensky (eds) *Games and Simulations in Online Learning Research & Development Frameworks*. Hershey, PA: Idea Group.

KEY TERMS

Adaptation: the intelligent alteration of any elements of a game for learning (e.g. educational content, presentation of that content, user interface, or game mechanics) In order to improve the educational effectiveness of playing that game for an individual student or groups of students.

Authoring tool: An application ideally designed for non-programmers to encode educational content for a game for learning or interactive training system.

Intelligent tutoring system: A digital learning experience that intelligently selects learning content and tutoring guidance based on a student model of the individual using the system.

Interactive story: A digital experience that involves the user, typically as a main character, in a structured dramatic experience that intelligently adapts to the player's actions as a character (e.g. selecting or generating plot content, selecting camera angles, changing scene lighting, etc.).

Knowledge trace: Used by intelligent tutoring systems to identify student proficiency across the target skills for a learning experience. Used for selecting lessons / learning content based on deficits in student aptitude.

Learning style: How individuals are best suited to experience learning content in terms of retention and comprehension.

Model trace: Used by intelligent tutoring systems to identify what knowledge students are applying to a problem. Used to select the ideal tutoring guidance to offer that student for a particular problem or situation.

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