Designing and Implementing Educational MUVEs (Multi-User Virtual Environments)

Steve M. Alessi
The University of Iowa
United States of America

steve-alessi@uiowa.edu

ABSTRACT
Multi-User Virtual Environments (MUVEs) are sophisticated simulation-games played simultaneously by a number of people. They can enhance student motivation and engagement through a combination of problem-based or project-based learning, social interaction, and collaboration. This paper describes the features of MUVEs with an emphasis on the concept of Total Environment Design, towards the goal of creating more effective learning environments.

KEYWORDS
Simulation, gaming, learning environments, instructional design, multi-user virtual environment, MUVE

INTRODUCTION
The lack of good educational software is frequently bemoaned and identified as evidence that educational technology is not living up to its promise. Indeed, much educational software does fail at being useful, effective, or both. But the reasons for that are many. To be useful and effective, educational software much have several characteristics, including (at a minimum) the following. It must be aligned with one's curriculum goals. It must be fun and interesting (i.e., motivating) for learners. It must be easy for teachers and learners to access and use. It must be flexible enough for successful use by students with different characteristics (e.g., ability, prior knowledge, and gender). It must have features that foster learning

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of the instructional objectives (such as integration of visuals and sound, relevant interactions, and support for metacognition). And it must be possible to see or assess that appropriate learning has actually taken place.

In other words, the creators of educational software must carefully attend to quite a large number of features to ensure the software is useful and effective. Much educational software is created with careful attention to some features but little attention to others. For example, a web site may teach some critical science concepts very well, but if it is not done in a way interesting to students, it will fail. Another web site may teach well and even be fun for students, but if it is too difficult for teachers to install and run on the computers available in their school, it too will fail. It is, unfortunately, a nearly all-or-nothing situation. That a program is good with respect to, let us say, 60% of these important characteristics, does not mean it will be 60% effective. Educational software must be good with respect to all important factors or it will be a failure for most users.

Furthermore, success depends upon more than just the internal features of software. It depends on the school context in which it is used, how it is introduced by teachers, used by students, and followed up with other educational activities. Thus, for a web site, a multimedia program, or any educational technology to be effective depends on what I will call Total Environment Design. This is a term I borrow from the environmental sciences. Environmental scientists are of course concerned with Earth's environment (the conditions of the oceans, atmosphere, land, weather) and are saying that we must engage in activities good for all aspects of the Earth environment if we are to successfully protect the Earth as a whole. I'm talking about Total Learning Environment Design and I'm similarly saying that for educational software to be successful, we must engage in activities relevant to all aspects of the software's design, implementation and context of its use.

Later in this paper I will say more about Total Environment Design and what considerations must be included. But first I would like to talk about educational Multi-User Virtual Environments (MUVEs), which outside of the field of education are known as Multi-User Domains (MUDs). The reason I will speak about them first is because I believe this is a type of educational software with great potential for facilitating Total Environment Design and thus more effective educational technology. Designers typically classify educational software into general categories such as tutorials, drills, simulations, games, hypermedia, and the like. An educational MUVE is a combination of simulation and game with several important characteristics (e.g., they are networked, they utilize the principle of collaborative learning, they are realistic) that make it more likely to facilitate Total Environment Design than, for example, simple tutorials or drills. That is not

to say that one cannot pursue Total Environment Design with a good simulation or a good hypermedia web site, but only that educational MUVEs have some built-in advantages for doing so. Therefore, in this paper I will begin with design characteristics and suggestions for educational MUVEs, after which I will make design suggestions characterizing Total Environment Design within the framework of Multi-User Virtual Environments.

EDUCATIONAL MULTI-USER VIRTUAL ENVIRONMENTS

Multi-User Domains (MUDs) became popular two or three decades ago with the advent of entertainment games such as Dungeons and Dragons [23]. In fact, the acronym MUD originally referred to Multi-User Dungeons and only later became more generally known as Multi-User Domains to reflect that they were not just about that one type of game. A domain could be any virtual world such as a family, a town, a company or a country. Still, they were mostly action games in which a number of people simultaneously played via computers connected to the Internet. Each real person in a MUD is represented on the computer screens of other players with an "avatar", an image of a person. The player controls his or her own avatar and interacts with other players via their avatars in the virtual world. A very popular web-based MUD you have probably seen or heard about is the Second Life web site (http://secondlife.com). Another popular MUD played on video game consoles such as Nintendo is The Sims (http://thesims.ea.com/).

In the 1990's educators began experimenting with MUDs for educational purposes, eventually changing to the acronym MUVEs to reflect their educational (in contrast to entertainment) content and purpose. Some of these, like River City [19] used visual avatars that look like people while others were primarily text-based virtual worlds in which the multiple users interacted in chat rooms. An example of the latter, though no longer operating on the web, is Pueblo Lindo [11]. It is a fictitious town in an unnamed Spanish-speaking country intended for American students learning Spanish. Multiple users could visit various locations in the town (such as the library, the museum, or a restaurant) and interact with other users, some of whom were native speakers of Spanish and some of whom were other American visitors.

In the last few years several research and development projects have used MUVEs in science education. The aforementioned River City project allows students to investigate health problems in the virtual town of the same name. Some of the avatars in River City represent other real students and some are virtual citizens. The students, via their avatars, interview other citizens and collect health-related data (primarily concerning an illness inflicting the town) towards finding and solving the problem. Other such projects based on MUVEs include Whyville [20] which focuses on both science and math, and Quest Atlantis [4] which combines science and social science themes and problems. At the University of Bergen in Norway we have been creating a MUVE for training government workers about planning and managing a nation's economic, social, and environmental needs [22]. So MUVEs are not just for children. They can be used for quite a variety of subject areas and for learners from childhood to adulthood.

The basic idea of educational MUVEs is to create a virtual world in which the multiple users can learn about the subject area (e.g., environmental science, economics, government planning) in a realistic way, that is, in a way which parallels the application of that subject area's content in the real world. Two key assumptions underlying the educational use of MUVEs are that by learning about content in a manner very like its application in the real world, the learners will be [1] more engaged, interested, and motivated, and [2] will experience better transfer of learning from the virtual world to their activities in the real world. That brings us to a discussion of the design features an educational MUVE has or should have.

DESIGN FEATURES OF EDUCATIONAL MUVES

Include multiple real users. The most obvious feature of a MUVE, implicit in the term, is that there are multiple users. Theoretically this can be from just two people to millions of people (as in the case of Second Life, an entertainment and social MUD played all over the world). The creators of MUVEs sometimes implement "virtual player" features so that a single student can work within a MUVE even if there are no other real students available. But allowing a single user to operate within the environment may negate some of its advantages such as the social and motivational aspects of interacting with real people, the intelligent actions of real people (still considerably more sophisticated than the artificially intelligent actions of virtual people) and the cognitive advantages of collaborative learning. In fact, a major research question that requires addressing is that of balance between avatars representing real people versus avatars representing virtual people. To put the research question simply, how many virtual people can you have in a MUVE before it is just a simulation with pedagogical agents, and loses the advantages of true human-to-human interaction? Thus, my first design suggestion is that even though there are some advantages to virtual players, MUVEs should depend primarily on the interactions of real people within the virtual environment.

In addition to the issue of how many users are engaged in a MUVE at any particular time is the equally critical issue of the potential user population size. Web-based

MUVEs especially are dependent upon a large enough population of users such that when any individual engages the program, there are other users on-line with whom they can be engaged. One of the failures of the Pueblo Lindo project (discussed earlier) was that it assumed and even depended on participants from Spanish-speaking nations being on-line at the same time American (English-speaking) participants were on line, so that the American students could benefit from conversation in Spanish with native speakers. Unfortunately, there was little in Pueblo Lindo to entice participants from Spanish-speaking nations and little benefit for them to use it, since it was an environment for learning Spanish and they already knew Spanish. Furthermore, time differences across time-zones (especially between the United States and Spain) made synchronous use of the environment by a critical mass of both native and non-native speakers very inconvenient. For an educational MUVE to be successful it must have appeal to a large enough population of users so there will be a sufficient number of users on-line and using the environment at any point in time.

Network as widely as possible. MUVEs depend upon the users being connected so they can access the common databases and programs which define the virtual world, and so they can interact with each other by modifying those databases which keeps track of the activities and attributes of all the avatars and objects in the virtual world. At the simplest level, a MUVE can be implemented for a small number of participants using the same computer and either taking turns at the keyboard or using different game-console controls. This is done with some versions of The Sims using video game consoles. The single computer (or game console) maintains the database and program. At the next level of size and complexity, one can use a local area network to implement a MUVE, as we are currently doing in the BLEND project. The local area network's server maintains the database and program while the different users work on different computers. This approach allows more users than the single-computer approach, though far fewer than are possible on the World Wide Web. But it is easier to program and provides better security and speed (responsiveness) then does the web and of course can be implemented without the ongoing expense of high-speed Internet connections. The current version of BLEND was implemented on a local area network because it is just a prototype. Our next version of that environment will most likely be implemented on the Internet. The Internet/web approach allows the best means of distributing a MUVE to a large number of participants, is more independent of equipment and software types (e.g., Windows versus Unix versus Macintosh), and provides access to the many other advantages of the web, such as its communication features, other web sites, and its global reach. When the security of the MUVE's content is of concern, the intermediate solution of using an Intranet is possible. This may be necessary for military training or when company trade-secrets are involved. However, is rarely an issue for MUVEs used by students in public schools or universities. The full advantages of MUVEs for education will be accomplished when it is implemented on the Internet, and should generally be implemented in that way unless there are good reasons to the contrary.

Be reality based. Probably as obvious as the presence of multiple users is that a MUVE attempts to imitate some aspect of reality, whether it be a profession (such as a MUVE representing doctors and nurses in a hospital), a place (like River City and its inhabitants), or an activity (such as planning the budget for a nation). In some cases the educational objective is to actually learn about the profession (being a doctor) but in other cases the presence of professions is just a means to an end, that is, a more realistic and interesting way for secondary-level students to learn about health and nutrition. The realistic nature of a MUVE can vary considerably. Some are visually very realistic (with images of animated people) but linguistically quite unrealistic (decisions and activities being performed by simple commands or typing). Some are not very realistic visually (they may present information in a completely textual and numeric fashion) but are quite realistic in terms of the cause-and-effect relationships being learned. The latter depends on the realism of the underlying simulation model. The level of realism should be based on the characteristics of learners (especially their prior knowledge of the area and their experience with the particular MUVE) and the instructional objectives. As with simulations in general, I recommend that realism be lower for novice students or those using an environment for the first time, and greater for more experienced students [2].

Models should be partly visible and controllable. All MUVEs have some underlying simulation model. These are typically quite complex models with multiple parts. For example, a MUVE may contain a model of ecology including the effects of people on the environment, plus a model of society and its forces that affect human behavior (such as conserving versus not conserving environmental resources), and the interconnections between the ecology sector and the social sector. In Whyville [20] a virtual disease called Whypox is spreading. That disease and its spread is part of the entire Whyville model. In most MUVEs, a key learning objective is for students to learn about some part of the model (for example, how a disease spreads) by exploratory activities within the MUVE. But it is not necessary for the entire model underlying the MUVE to be an object of the students' learning. Many parts of the underlying model are just there to enable the complete environment. In Whyville, students should learn about disease transmission, not the general

activities of society or running of a town. But those aspects of the model must be present to give the environment completeness and make it a life-like, interesting, and motivating one to work with. To accomplish this, when creating the underlying model, the designer must carefully assess which model variables are present but should be neither seen nor manipulated, which model variables are present and seen but not manipulated, and which model variables are present, seen, and manipulated [1]. The latter (variables which are present in the model, seen by the users, and capable of being manipulated by the users) should be carefully chosen based on what knowledge you intend to convey. Designers should take special care to avoid allowing too many variables to be seen and changed.

Control complexity. Although all educational MUVEs are complex by virtue of their underlying simulation models, they can vary considerably in their complexity. The degree of complexity is a double-edged sword. The more complex, the more likely it is to maintain the interest of students and do so for long periods of time. Additionally, the more a MUVE imitates reality (that is, the more realistic it is) the more complex it will be, and that generally implies greater transfer of learning to real-world activities [3]. On the other hand, complexity may lead to frustration and "giving up" both on the part of students and teachers. Indeed, research with some MUVEs has suggested that students do not persist for very long in complex and difficult MUVEs [19, 14]. Thus, designing to achieve the proper level of complexity requires balancing issues of challenge, satisfaction and transfer. Like realism, complexity should be appropriate to the educational level of the learners and their experience with the MUVE. As learners gain more experience with the environment, complexity may be increased.

Use multiple modalities and consider individual differences. MUVEs vary widely in the way they incorporate different modalities. Some are largely text based, some use sophisticated computer animation, some video and audio. The choice of modalities is often made based on the content. Some content is much more visual or aural in nature than other content which is more verbal or numeric. But different modalities can also accommodate learners with different characteristics or needs. Use of voice may benefit young students who cannot yet read or students with visual disabilities. Use of text can benefit students with aural disabilities or adults with good reading ability and perhaps a preference for reading over listening. Choice of modalities can also affect motivation, ease of use, and content clarity. As an example of the latter, learning spatial information (such as maps) is generally facilitated by visual modalities such as pictures while sequence and temporal information (such as meter in poetry or syncopation in jazz) is better facilitated by aural information such as speech or music [10]. Finally, there is ample evidence that the right combination of sensory modalities, such as animation with voice narration, can reduce cognitive load and facilitate learning, while the wrong combinations, such as voice narration accompanying a text that is dissimilar, can greatly diminish learning [16, 7]. I would generally recommend providing multiple sensory modes (especially graphics and animation with voice), giving users options (such as to turn voice or text captions on and off), and avoiding those combinations known to be problematic for learning, such as simultaneous text and voice.

Design for gender neutrality. A particular individual difference that challenges teachers all the time is gender. Young girls and boys have different interests and motivations. Fortunately, there is some evidence that MUVEs are enjoyed by young girls as much as they are by boys [19, 18]. This has not been the case with regular computer and video games. Commercial video games often glorify warfare and violence and are preferred far more by boys than by girls. But educational MUVEs are often based upon themes of communication, cooperation, socializing, and improving the world. Those are themes that young girls enjoy as much as, and perhaps more so than boys. For this reason there is justifiable hope that well-designed MUVEs will appeal to both genders and level the technological playing field for them. But attaining that goal depends on designers choosing themes and activities with equal appeal to both genders, and not taking the easy road of choosing themes and activities that young boys most enjoy.

Simulate authentic problems or projects. A primary reason behind the interest in MUVEs is that they support the instructional strategies of project-based and problem-based learning. Furthermore, a well-designed environment can provides problems or projects that are similar to the ones encountered by people in the real world, such as doctors diagnosing patients' illnesses or environmental scientists investigating the causes of pollution in a river. Projects and problem solving done by professionals in the pursuit of their actual jobs are what we call authentic problems or projects. They are in contrast to the problems and projects often assigned as schoolwork like a chemistry lab or a book report. But note that I have said MUVEs simulate authentic problems or projects, because they are not real activities in the real world. They are activities in the simulated world which imitate those of the real world. If a science teacher takes his or her students out on field trips to collect air and water samples and do research on local pollution problems, that is authentic activity. When the students do that same research in a MUVE it is simulated authentic activity. Although simulated authentic activity may be more enjoyable and valuable than traditional schoolwork, we should not assume that it is more enjoyable and valuable than, or even equivalent to, truly authentic activities. On the one hand, real "field work" tends to be more interesting and exciting. On the other hand, the

simulated activities of a MUVE may allow students to virtually engage in activities which would not be possible in the real world, because of cost, danger, time or other difficulties. The recommendation here is to use projects and problems which are as similar as possible to the ones we encounter in the real world [17].

Integrate across subject areas. Educational MUVEs can combine aspects of several subjects that students are studying in school. A single MUVE may incorporate principles and problem solving in science, in math, in social studies, and in the language arts. Cross-curriculum activities not only make the projects and problems in a MUVE more varied and interesting, they also make them more useful for a variety of teachers. However, most MUVEs to date have emphasized science to a great extent, so while they have potential for cross-curriculum subject integration, that potential has not yet been fully realized. I content that in the future, the more successful MUVEs (those which are not only effective when used, but which are used and continue to be used) will be cross-curricular so that they appeal to many teachers and serve many educational goals.

Design for long-term use. The full use of a MUVE (wherein students solve a problem or finish a project) can take days, weeks or more. This is both a potential advantage and disadvantage. Positively, it provides the potential for supporting instruction of sizable content areas or difficult objectives that require significant time to master. Negatively, it requires a considerable commitment of time by a teacher and competes for time with other classroom activities. That can dissuade many teachers from using them. There is probably need for both types of environments, those which are designed for long-term use and those which can be used and completed in a shorter amount of time. But MUVE's designed for long-term use, like cross-curricular ones, will be more generally useful and less likely to fall into disuse.

Provide support and scaffolding, both programmed and live. MUVEs can incorporate instructional support and scaffolds for learning by virtue of two complementary characteristics – they are computer programs and they incorporate other live actors (through their avatars) including other students, teachers and subject matter experts. It is becoming increasingly clear that while exploratory learning environments have many benefits, we cannot just depend on students learning by exploring. Students require support when material is challenging. But not so much support that they (the students) come to rely upon it. The notion of learning scaffolds is that of providing just enough support for students to be able to accomplish challenging tasks primarily on their own, with the scaffold gradually withdrawn as the student begins to accomplish tasks more independently, and thereafter used only for more difficult challenges that the student cannot yet do without help. Because MUVEs are computer programs, they can include pre-programmed support features such as help sections, hints, virtual coaches, and pedagogical agents. Additionally, because MUVEs incorporate real people, those other people can serve as helpers to learners experiencing difficulty. In particular, teachers can participate in the action of the MUVE and via their avatars can provide more intelligent help than pre-programmed agents currently can. Finally, if a MUVE becomes large and popular enough that it attracts many participants from a wide variety of locations and with a wide variety of skills, there will be live participants other than teachers capable of providing help and hints. This is how things are in the real world. In business, in government, or in any realm of human endeavor, we seek out and obtain assistance from consultants or colleagues with expertise we do not yet have. MUVEs can replicate that aspect of the real world just like they replicate the tasks, problems, and activities of the real world. Thus, the larger a MUVE is designed to be (in terms of the number of simultaneous real users) the more likely it is to provide natural support and scaffolding via the other users, and in ways instructors and designers cannot often foresee.

Practice Total Environment Design. A MUVE is a type of learning environment, but it is not a complete learning environment (in the sense I mean when using the phrase Total Environment Design) because it does not include the real teachers, other real students, physical textbooks, and the real world in general. Total Environment Design means implementing and coordinating electronic media, human beings, real physical artifacts, school objectives, and other essential aspects of the complete real-world educational environment in such a way that it continues to function effectively over time and for all the participants in the educational enterprise. As I said at the start, I believe the failure of designers to attend fully to all aspects of the educational environment can account for the failure of many technology "solutions" in education. Those supposed solutions are created in a research laboratory or publishing house and transplanted into real classrooms with little attention to whether they can thrive there. It is like taking a tree from the rain forest and planting it in the desert. I will go a little further, beyond technology, and say that many educational materials and innovations fail because they are transplanted into a new environment without attention to or modification of the environment. We often do this. We install new materials or innovations into schools and expect them to just work. But they often don't. Many textbooks or other print curricular materials fail to succeed because they are not compatible with the school environment and the school environment is not modified to accommodate the new materials. Many teachers fail for the same reason. They don't fit in to a particular school environment, their goals are not compatible with the school's curricular goals, or their skills are not compatible with the characteristics of the particular students they are expected to teach. For things

to succeed, the parts of the educational environment must be coordinated to work well together. So let's look at the concept of Total Environment Design, especially as it applies to the creation and implementation of Multi-User Virtual Environments in the classroom.

TOTAL ENVIRONMENT DESIGN WITH MUVES

As stated earlier, many educational technology programs fail to be useful or effective because of incomplete design. Either essential characteristics of the programs were ignored or essential characteristics of the environment in which the programs are to be employed were ignored. Many more instructional programs would prove successful if all essential features were carefully designed and implemented. The most critical aspects of Total Environment Design include the following: The materials and student activities should be aligned with worthwhile objectives. Students should find the materials and activities engaging and motivating. Both students and instructors should receive support for their corresponding learning, teaching and management roles. Technology should play an appropriate role. Learning should be collaborative and community oriented. Learning should be centered around realistic problems or projects. Problems and projects should be complemented by relevant just-in-time learning. Assessment should be designed and administered to support student learning and provide guidance for selection of learning activities and sequences. The environment should be ongoing, long term and cumulative in nature. The environment should allow flexibility for different students and teachers and their educational needs. The environment should allow for growth, that is, it should allow for modification based on its use and assessment to ensure better learning by more students in the future. Let's consider each of these.

Align with worthwhile objectives. Many educational programs are created because someone has a clever idea, but without considering whether the programs teach something that students really need to learn or which is part of a school curriculum. Alternatively, some programs start out with particular worthwhile objectives in mind, but veer off track and in the end teach something else. This is not a question of effectiveness but of usefulness. To be successful a program must be both useful and effective. To be useful a program must teach something that is in the curriculum (and hopefully should be in the curriculum) and is beneficial for students' current or future lives. The starting point of a good learning environment is that it serves an agreed upon purpose. Educational MUVEs have no inherent advantage with regard to this type of alignment. But their ability to integrate learning across multiple domains may make alignment easier, if designers take advantage of that ability. My recommendation is to create environments that facilitate a number of worthwhile school objectives and keep those objectives clearly in sight as the environment is developed and deployed.

Maintain motivation and engagement. Although everyone speaks of the importance of motivation, they often claim it is the responsibility of somebody else. Teachers say that students must "be motivated" as if it was purely the responsibility of the students themselves. Designers of learning environment claim that "teachers must motivate their students" as if it was entirely the teachers' responsibility. Ensuring motivation is very difficult and is the responsibility of everyone, so all participants have a role. Students enter any situation with some (even if poor) motivation. Teachers must work with whatever motivation students enter with and do what can be done to increase it or sustain it. Designers must intentionally include features in educational software which increase students' motivation and provide teachers with additional tools for doing so. Several educational motivation theories provide guidance towards designing for motivation [12, 15]. Some evidence suggests that the most important feature for motivation is that students see the objectives as relevant to their current or future lives [21]. Other evidence suggests that intrinsic motivators like social interaction are more powerful and long-lasting than extrinsic ones like grades [13]. Being games (or at least being similar to games), MUVEs have a built-in advantage, at least at the start, for motivation design. But it is insufficient to simply engender motivation at the start, such as with an interesting premise. Motivation must also be maintained throughout instruction. This can be done by ensuring that the content really is relevant, that it is constantly challenging at the right level, and that it is fun. Designers often assume that games are fun simply because they are games. But we have all started playing games that we ultimately did not enjoy and stopped playing. Designing games that most people really consider to be fun is not an easy task. It requires attention to good storylines, rules, action, surprise, and so on. At the risk of being repetitive, designers cannot put too much emphasis on motivation, and should do everything they can to improve and maintain students' motivation over the level they arrive with.

Aside from being a type of game, a well-designed MUVE contains the same kind of motivators that exist in the real world such as social interaction with real people and engaging in real-world activities. These motivators are in considerable contrast to the artificial motivators typical of most school work such as grades and teacher approval. Motivating all students is a continuing challenge for teachers and well-designed MUVEs have great potential for creating and maintaining student motivation through an ongoing course of instruction. The more intrinsic and continuing motivators inherent in MUVEs can provide teachers much needed

motivation support.

Closely related to the issue of motivation is that of student engagement. Many teachers report that even though their students do the assigned work, they just don't seem engaged. By that they mean the students don't appear to be trying hard, exerting effort, or persisting in the face of difficulty over extended periods of time. Even students who express interest or show signs of motivation at the beginning will often give up too quickly. They take shortcuts, ask for help instead of trying to figure things out themselves, and avoid more difficult problems in favor of easier ones. A common claim of MUVE enthusiasts is that because they immerse students in the virtual environment, they keep students engaged. I would agree that they have this potential. Unfortunately, researchers have reported that even interesting MUVEs do not always succeed in engaging all students [19, 14]. Many students just go through the motions. They explore all the interesting places, have dialog with the real and virtual avatars, collect artifacts and information, and perform all the easier tasks. But they fail to generate and test hypotheses, address and solve the key problems, or finish the important projects. To me, it is another example of students becoming "browsers" on line. This is a problem that all teachers using multimedia or the web have noticed. Even good students who carefully read and study traditional textbooks will, when they are on the web or using multimedia programs, switch from being serious readers to being browsers. What does it mean to be a browser? They quickly jump from page to page, skip large sections of material, get distracted by links to other web sites, and fail to engage in good study strategies like taking notes. We must not assume that MUVEs will automatically engender sustained engagement in all students. Only through good design will they do so. Such good design includes having an interesting storyline, roles that the students want to take on, activities that not only look exciting at the beginning, but are exciting to accomplish because they have consequences that students find worthwhile or desirable. It cannot be stressed enough, instructional materials that keep students engaged are the most likely to succeed in their objectives. MUVEs have the potential for good engagement, but engagement is not automatic just because you employ a MUVE. Engagement requires careful design and implementation.

Provide instructor and learner support and scaffolding. As alluded to earlier, another reason educational innovations tend to fail is because they are difficult for teachers to implement or for students to use. Roadblocks include everything from software installation and equipment incompatibility to figuring out how to help students when they run into difficulty. This can be true for individual multimedia lessons and web site, but is especially problematic for large learning environments that require coordination of multiple students and media. Total Environment Design also means supporting teachers in all their activities (installation, managing the student activities, maintaining materials, assessing success) through features such as on-line tools, print manuals, telephone help-lines, and users' groups. Students need support as well but of two very different types. Like teachers, they need logistic help with, for example, on-line navigation, sequencing between on-line and off-line work, and keeping track of where they are from day to day. But students also need content help. Not all content help should be on-line and within a MUVE or other software product. Content help should be available from teachers, other students, and books. A total learning environment must be designed so students can get content help from a variety of sources and media, whenever and wherever they need it.

Give technology an appropriate role. Technology enthusiasts want to use technology for everything and solve all educational problems entirely with technological solutions. This attitude is evident in the "e-learning" movement which, by its very name, suggests learning pursued entirely by electronic means. The extent to which technology should be used will vary depending on the subject, the students, and the teacher. But on the average, I believe that the proportion of a student's learning activities that should be technology-based is in the range of 20 to 30 percent of all a student's learning activities. Even in most web-based courses, students devote the majority of their time and effort to traditional off-line activities such as reading textbooks. Creating learning environments based on much larger percentages of technology use will likely be stressful for many students and teachers, hamper motivation of both, and be less effective than if they took greater advantage of high-quality traditional materials (rather than attempting to replace them with newer, untested, and possibly lower quality electronic materials). Total Environment Design should be based on a wide variety of instructional media and methods including print materials, electronic materials, field work, library and laboratory research, and of course face-to-face interaction among students, teachers, and experts. Even though all the materials in a library can be digitized and placed on the Internet, some students will have better access and more success learning if they can use traditional library materials. Providing students choices among media will benefit all students logistically and many students cognitively. Similarly, the face-to-face interactions of people are very important for many aspects of learning and motivation. Finally, when it comes to designing and developing the technology-based parts of a learning environment, they should be selected to take advantage of the technological features available. For example, creating web sites as part of a learning environment should be done to capitalize upon particular features of the web, such as its worldwide communication capabilities, its ability to link to other

web sites, or its ability to deliver updates quickly to a distributed population of students.

Establish community and facilitate collaboration. Significant work in the last two decades gives support to the argument that learning and motivation are greatly facilitated by collaborative learning, especially when implemented in what are called learning communities or communities of practice [6]. Students and teachers learning together while working on worthwhile projects is beneficial because they support each other in their work and learning, create social motivation (students are more likely to complete work if peers are dependent on them), and because the different individuals bring different background knowledge, skills, and abilities to the effort. MUVEs provide a good foundation for community and collaboration because they are multi-user environments, because collaboration can be facilitated in a variety of ways (such as teamwork and between-team competition) and because they possess electronic memory of communal activity. But the total environment (the classroom, the school, the real world) in which the MUVE is located should also be considered and designed to foster community and effective collaboration.

Center activities around realistic projects or problems. Like collaborative learning, project-based and problem-based learning shows great promise for effective learning environments [5]. They provide a purpose for activities. When the problems or projects are similar to those done by professionals in the real world, they not only have added motivational value (by virtue of their relevance) but they also can facilitate transfer of what is learned to subsequent learning and to real-world activities. Because MUVEs allow students to pursue problems and projects in a virtual (simulation) environment, they can include problems or projects that would be too expensive, time consuming, dangerous, or inaccessible in real life. This is not to say, however, that projects or problems should only be pursued within virtual learning environments. In a total learning environment, students should pursue some problems in the virtual world and other problems in real laboratories. They should do some projects in a MUVE and others as field work outside the classroom. Such combinations of virtual work and real-world work have multiple benefits including the facilitation of initial learning, motivation, transfer, and assessment.

Provide just-in-time learning opportunities. Acquiring new knowledge makes much more sense if you do it "right now" because you need that knowledge for a current activity. Knowledge you need is really relevant to you, so acquiring it is much more motivating than, for example, knowledge a teacher tells you will be important "someday". This is the idea of just-in-time learning, and it is supported in turn by the previously discussed use of realistic projects and problems. When students are engaged in a project they will frequently encounter a need (for a skill or for knowledge) they have not experienced previously. Fulfilling that need is just-in-time learning. Well chosen problems and projects can lead students to "need" new knowledge and skills that are part of the school curriculum, and they will probably learn them better and more willingly than if they are just told "it's part of the school curriculum". Total Environment Design dictates arranging the environment so that students are not assigned content for contents sake, but will naturally come to need the new knowledge and skills and go about acquiring them through the tools provided in the learning environment.

Use assessment to guide learning activities. Assessment is a frequent activity in education but more than anything else, it is used for purposes such as grading and placement. Within Total Environment Design, assessment should be embedded within the learning activities so as to provide instructional guidance information. That is, assessment should expose what learners do and don't know or can and can't do, towards the purpose of helping them remedy their don'ts and their can'ts. Embedded assessments can also provide learners with information towards greater self-awareness, hence improving their metacognitive capabilities [9] as well as their cognitive capabilities. Embedded assessments are those which are built right into the instructional activities rather than looking like separate tests or quizzes. A MUVE can collect performance data concerning students' decisions, for example, which instructors can view and use to advise students about what they should be doing next. Outside of the MUVE but still within the total learning environment, many kinds of student activities (live presentations, group discussions, blogs) can be recorded and can serve as embedded assessments for guidance of subsequent learning activities.

Design the environment to be ongoing and cumulative. The world of educational research and development is full of interesting projects which, though they showed great promise, have neither come into widespread use or even endured. The "Adventures of Jasper Woodbury" programs from Vanderbilt University [8] were in their day, creative, based upon sound educational theories, and effective. In several research studies they demonstrated excellent cognitive and affective outcomes. But after an enthusiastic reception and a spurt of growth, they have stagnated. They have failed to attain widespread use. In schools that once used them, they are no longer being used. The original dozen or so adventures have not been added to. The technology underlying them (analog videodisc) is all but obsolete and the programs do not appear to have been ported to newer technologies like DVDs or streaming web video. There are many reasons for this and other examples of good innovations fading from the scene, but those reasons are not my interest. The important point is that when considerable effort and money is expended to create effective learning

environments, effort should also be devoted to ensuring that they will continue and spread. Furthermore, such environments should be designed so that new material, even from new subject areas, can be added, and for the program to be used not in a single year of schooling but to stretch across grades so they can be used repeatedly by students as they progress from grade to grade and subject to subject. This is an aspect of design that researchers in the field of instructional design have not really addressed, namely, how to design learning environments that (assuming they are instructionally effective) have built-in longevity, continuity, and expandability. Older technologies such as "the book" have proven very successful because, among other things, they have longevity, continuity, and expandability. I think it certain that for newer technologies to be as successful as books have been, we must also figure out how to design them to have the same qualities, and that should be a part of Total Environment Design.

Ensure flexibility for learners and instructors. Let's continue the book comparison for a moment. Although we may think of books as simple fixed objects, they are actually very flexible in their form and their use. Books can be all sizes and shapes. They can have pictures and photographs as well as text and tables of numbers. They can provide tools such as indexes, tables of contents, tabs and bookmarks. In terms of their use, they can be purchased, loaned and traded. We can write in them, photocopy them, and tear pages out of them. We can collect them at home or put them in libraries. When reading a book we can jump instantly to any page and read pages in any order we want. We can read them ourselves, read them to our students, or listen to someone else reading a book. I could go on. Are most electronic technologies this flexible? True, they can do some things that books cannot (such as including animations, voice, or movies). But it's difficult to write marginal notes or to underline words in most software, to "tear out" something interesting, or to study a multimedia program in any sequence you like. Indeed, not all of these things may be desirable. I mention them only as examples of flexibility. But the fact remains that many learning environments are not very flexible and both instructors and students are disadvantaged by that. Another component of Total Environment Design is therefore to ensure that an environment be as flexible as possible, both in terms of form and use, in ways that facilitate their goals and avoiding ways that hinder their goals. Like the previous discussion of designing environments with longevity, continuity, and expandability; making environments with a high degree of flexibility is not a skill that the field of instructional design has conquered. It remains an important area for future research and development. Within a particular MUVE, appropriate user control should be provided. Instructors should have options so they can customize the program to their needs and to the needs of their students.

In the total environment, instructor guides should suggest alternative activities, materials, and sequences to meet students' needs. The total environment should accommodate a reasonable range of class sizes. The possibilities for flexibility are many. The main point is that the environment should not be so carefully scripted and sequenced that there is little flexibility for teachers or students.

Build the environment for growth. Successful textbooks typically live on in multiple editions. With each new edition and based on input from readers, parts of a textbook are removed, added or changed. Content is updated based on advances in the field. Spelling and grammatical errors are fixed. Color diagrams may replace black-and-white ones. Separate instructor guides and test item banks may be implemented. In this way a successful textbook grows and improves. Another part of Total Environment Design is to allow for such growth of the materials and activities of that environment. We have not seen much of this to date, perhaps because few learning environments last for very long, as was discussed above. Perhaps they do not last long because they are not improved. If a textbook author does not update a textbook to a new edition, teachers who once assigned that textbook will eventually stop assigning it. So it will likely be for learning environments. They should undergo data collection and evaluation and be revised based on input from students and teachers. This is an activity that instructional design has excelled at and provides extensive advice about. More than anything else, good instructional design is an iterative process of developing, testing, and revising materials and procedures. That iterative process needs to continue after the learning environment has gone into regular classroom use. A learning environment can facilitate its own growth and improvement by collecting data (perhaps doing so with embedded assessments) and being designed in a flexible enough manner that iterative change is possible. Commercial MUDs like Second Life are designed for growth, and their use is spreading worldwide as a consequence. Most educational MUVEs have not been designed for growth (admittedly because most have been created as research or demonstration programs) and probably as a result they are not spreading. If you are designing a learning environment that you really do wish to see spread to many schools, you must design for its improvement and growth.

CONCLUSIONS

Many educators complain that electronic technologies have not lived up to their early promise. This is both true and is a serious issue, for it threatens investment in technology for schools and gives many people who are uncomfortable with technology a good excuse to avoid using it. Why do we find ourselves in this situation and how do we solve it? Although I would not say it is the full story, I believe a large part of the problem is very incomplete design of technology solutions. Successful programs require attention to all the critical issues: worthiness of objectives, motivation and engagement, support for all users, good instructional strategies, flexibility and potential for growth. Only if we adapt a more holistic approach will we create learning environments that are enjoyable, are instructionally effective, and will last as long as a good book.

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