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Simulations: Bringing the benefits of situated learning to the traditional classroom

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Introduction

Like other instructional methodologies, traditional classroom instruction has its strengths and limitations. These have been well-documented in the literature and continue to be a source of research and discussion. An issue which has captured the interest of some researchers is the extremely limited inclusion of real-world learning experiences in the traditional classroom setting (Duffy & Cunningham, 1996). For the most part, the content presented in the classroom is disconnected from its real-world context. Knowledge conveyed in the classroom tends to be situated in the context of the classroom and the school rather than the context in which the knowledge was created (Henning, 1998). This contextual dichotomy has been shown to negatively impact the learning process, adversely effecting learner motivation in particular (Henning, 1998). At the same time, real-world learning situated in real-world contexts has been shown to have positive impacts on learning and learner motivation (Duffy & Cunningham, 1996). How can we bring the benefits of real-world, situated learning to the traditional classroom? Educational simulations may provide one solution (Hung & Chen, 2002). In this paper we will discuss the role simulations can play in providing at least some aspects of real-world learning in the traditional classroom. Three examples of classroom situated learning facilitated by simulations will be presented and discussed. Prerequisite to our discussion it is appropriate to provide definitions of the terms, “educational simulation” and “situated learning.”

Educational Simulations

A very complete definition of “educational simulations” can be found in Alessi & Trollip, 2001). The purpose of an educational simulation is to motivate the learner to engage in problem solving, hypothesis testing, experiential learning, schema construction, and development of mental models (Winn & Snyder, 1996; Duffy & Cunningham, 1996). To facilitate learning, educational simulations rely heavily on scaffolding (Duffy & Cunningham, 1996), coaching, and feedback (Alessi & Trollip, 2001).

An educational simulation is based on an internal model of a real-world system or phenomena in which some elements have been simplified or omitted in order to facilitate learning. The models on which educational simulations are built tend to be of three general types: continuous, discrete and logical.

- *Continuous models* are constructed using calculus in order to represent a system with an infinite number of states.
- *Discrete models* employ statistics and queuing theory to represent systems with quantitatively discrete states.
- *Logical models* are most often represented using a set of heuristics implemented through a high-level computer programming language.

While logical models are utilized most often in educational simulations, continuous and discrete models are most often found in scientific and engineering simulations. An educational game should not be considered a simulation unless the game is built upon a model of a real-world system or phenomena (Alessi & Trollip, 2001). Educational simulations are generally grouped into four categories: physical, iterative, procedural or situational.

- *Physical simulations* allow the learner to manipulate variables in a open-ended scenario and observe the results. An example of a physical simulation would be a model of global weather patterns in which the student can manipulate certain parameters and observe the outcome.
- *Iterative simulations* tend to focus on discovery learning by providing the student with opportunities to conduct scientific research, build and test hypothesis and observe the results. This type of simulation typically focuses on teaching phenomena which are not readily observable in real-time, for example, phenomena from biology, geology or economics. In this case, the student would repeatedly run the simulation, altering variables with each iteration to test a hypothesis.
- In a *procedural simulation* the student manipulates simulated objects with the goal of mastering the skills required to correctly and accurately manipulate physical objects in a real-world setting. A typical example of a procedural simulation is a chemistry lab experiment in which the student manipulates simulated laboratory equipment with the goal of preparing the student for working in a real-world laboratory setting.
- *Situational simulations* generally model human behavior focusing on attitudes of individuals or groups in specific settings. These simulations often employ role playing as a vehicle to allow students to explore different options and decision paths. Situational simulations are usually designed to be run several times with each participant in the simulation scenario playing a different role in each iteration (Wilson & Cole, 1996). It should be noted that, because of their open-ended design, and due to the complexity of modeling human behavior, situational simulations tend to be the most difficult type of simulation to design and utilize effectively.

For all categories of simulation, fidelity refers to the accuracy with which the simulation models a real-world system or phenomena (Alessi & Trollip, 2001). Fidelity also refers to the realism of learner interaction facilitated by the simulation as well as the type and frequency of feedback provided. A well designed simulation can maintain a high degree of fidelity while abstracting or omitting distracting elements that would otherwise be present in a real-world situation (Alessi & Trollip, 2001; Moore, et. al., 1996).

Educational simulations have a number of advantages over other instructional methodologies and media. Students often find active participation in simulations to be more interesting, intrinsically motivating and closer to real-world experiences than other learning modalities (Alessi & Trollip, 2001). Simulations have been shown to provide transfer of learning with the result that what is learned facilitates improved performance in real-world settings (Leemkuil, et. al., 2003). Further, there is evidence to suggest that simulations may be more efficient modalities for learning in some content areas (Alessi & Trollip, 2001). Simulations can be very flexible in that both student and instructor can have a high degree of control over simulation variables (Duffy & Cunningham, 1996; Hung & Chen, 2002). Simulations allow students to experience phenomena which could be dangerous, expensive or even impossible to observe in the real world (Alessi & Trollip, 2001). For example, simulations permit the learner to stretch or compress time and space (Wilson & Cole, 1996). Because educational simulations are simplifications of real-world phenomena, they facilitate learning by omitting what would otherwise be distracting elements in a real-world situation (Alessi & Trollip, 2001). Finally, simulations can accommodate a wide range of instructional strategies, including microworlds, scientific discovery learning, virtual reality, laboratory simulations, role playing, case-based scenarios, and simulation gaming (Alessi & Trollip, 2001).

Simulations do have distinct disadvantages compared with other modalities. Because simulations are often used with problem-based learning methods, they stimulate learners to immerse themselves in a problematic situation and experiment with different approaches (Heinich, et. al., 1999). This type of learning may require significantly more time than other methods of instruction. Research has shown that, without appropriate coaching (Duffy & Cunningham, 1996), scaffolding (Duffy & Cunningham, 1996), feedback and debriefing (Leemkuil, et. al., 2003), the learner gains little from the discovery learning simulations can facilitate (Min, 2001; Heinich, et. al., 1999). In addition, research has indicated that, in the absence of reflection and debriefing, students tend to interact with a simulation as merely a game (Leemkuil, et. al., 2003). Some constructivists argue that educational simulations "oversimplify the complexities of real-life situations," giving the learner an imprecise understanding of a real life problem or system (Heinich, et. al., 1999). Finally, development of educational simulations may involve extensive planning and require significant investment of time, labor and financial resources.

Situated Learning

An outgrowth of constructivist theory (Land & Hannafin, 2000), a fundamental concept of situated learning is that all learning takes place in a specific context and the context significantly impacts learning (Alessi & Trollip, 2001). When learning is removed from its context, the value of the knowledge and the relevance of that knowledge to the learner become depreciated (Duffy & Cunningham, 1996). Learning which takes place in the limited setting of a school may constitute situated learning. However, classroom situated learning is implicitly based on school culture while being attributed to the real-world culture of practice (Brown, et. al. 1989). The impact of this dichotomy on the learner is often reduced motivation and cognitive dissonance (Henning, 1998). Abstract concepts like mathematics can be more easily mastered when taught in a real-world context than in the formal context of the classroom (Duffy & Cunningham, 1996). Situated learning involves a practice-based approach which tends to erase the dichotomy between school-based learning and real-world learning. Because situated learning can take place in settings that are culturally and socially diverse, the learning environment can be dynamic (Duffy & Cunningham, 1996). Consequently, situated learning need not employ the linear approach to instruction which is most commonly used in a classroom setting. Learning can occur naturally as a consequence of the learner recognizing the practical utility of knowledge conveyed as well as the need to use it to interpret, analyze and solve real-world problems (Hung & Chen, 2002). As a result, students engaged in situated learning activities tend to exhibit emergent meta-cognitive behaviors (Land & Hannafin, 2000). Finally, situated learning tends to be demand driven, either by the student or by some entity which needs or values mastery of a particular skill in a specific context (Hung & Chen, 2001).

A second key concept of situated learning is a collaborative process in which the student interacts with other members of a “community of practice” (Henning, 1998; Wilson & Cole, 1996; Duffy & Cunningham, 1996). The relationships among members of such communities tend to be peer-based rather than the more formal teacher-student relationship of the classroom. As the learner’s knowledge and skills increase, the role and status of the learner as a member of a community gradually evolves from that of novice or apprentice to expert. Part of the learning process is observing the actions and attending to the spoken communications of expert practitioners at work. As a member of a community, the student participates in learning tasks throughout the interval of instruction. Situated learning may also involve role-playing or scenario-based learning activities (McLellan, 1986). Assessment is often based on the degree of mastery demonstrated by the learner rather than on formal tests. Significant transfer of learning to settings outside the learning context is possible when situated learning is properly designed (McLellan, 1986).

A third key component of situated learning is the assumed presence of tacit knowledge (George, 2001). This is knowledge which experts have developed over a long period of time, but which they may not be able to articulate to a novice. While tacit knowledge can be difficult to define and communicate, it is often an integral part of the culture or community of practice.

Finally, everyday cognition is an integral part of situated learning and refers to the process of learning to use a tool or artifact in a real-life situation to accomplish a real-world objective (Henning, 1998). Because this type of knowledge is associated with cues from a real-world environment, it can be more readily recalled by the learner when needed (Moore, et. al., 1996). In the classroom context, everyday cognition is usually superseded by the procedural regimentation of the traditional classroom (Brown, et. al. 1989). This is unfortunate as everyday cognition is well suited to hypotheses testing and problem solving

Key strategies often utilized in situated learning environments include the following:

- stories,
- reflection,
- anchored instruction,
- cognitive apprenticeship,
- modeling,
- collaboration,
- coaching,

- scaffolding and judging,
- multiple practice,
- exploration and
- articulation
(McLellan, 1986; Brown, et. al. 1989; Duffy & Cunningham, 1996; Land & Hannafin, 2000).

Situated learning does have three significant limitations relative to other learning methodologies. First, situated learning programs are often very time-consuming to develop. Second, the success of situated learning often requires the participation of an active learner who is intrinsically motivated. Third, while situated learning may be suitable for many learning outcomes, it is not the most efficient methodology for teaching factual information or abstract, complex concepts (Chen & Hung, 2002).

Bringing Real-world Learning to the Classroom

It is probably impractical to consider transforming every classroom setting into a situated learning environment. However, it may be possible to bring at least some of the benefits of situated learning into the conventional classroom setting. Educational simulations may make this possible.

Educational simulations can provide a method for students to check their understanding of the real world by modeling the structure and dynamics of a conceptual system or a real environment. Simulations facilitate situated learning by providing interactive practice of real-world skills, focusing on the essential elements of a real problem or system (Heinich, et. al., 1999). Educational simulations can “communicate complex and technical scientific information” (Saul, 2001). A well-designed simulation can engage the learner in interaction by helping the learner predict the course and results of certain actions, understand why observed events occur, explore the effects of modifying preliminary conclusions, evaluate ideas, gain insight and stimulate critical thinking. Educational simulations can also provide the learner with “feedback throughout the learning process” (Granland, et. al., 2000). Because of the dynamism inherent in simulations, they can guide the learner in the achievement of specific learning goals (Gibbons, et. al., 1997). It seems apparent that many benefits of situated learning can be provided to the learner in the traditional classroom through the use of educational simulations.

Just as each learner has a different learning style, there are many types and degrees of situated learning. Chen & Hung (2002) present situated learning as occupying a continuum of instructional contexts ranging from “authenticity to generalizability.” The authors assert that with appropriate scaffolding, simulations can serve in the mid-range of this continuum by providing real-world problem-based learning. However, this functionality can be provided only when simulations allow both student and instructor the widest possible range of variables which can be set and manipulated. In so doing, simulations can approach the realities of a situated learning context.

The instructional use of simulations is a relatively new phenomena about which research is limited. Even so there are ongoing efforts towards developing and evaluating the use of simulations to facilitate situated learning. To address the effectiveness of simulations as a modality for situated learning, three research projects will now be presented.

Transfer of Mathematics Skills

Van Eck and Dempsey (2002) reported on testing a computer simulation designed to facilitate transfer of mathematics skills from a learning context to a real-world scenario. The simulation software was developed using Macromedia® Authorware® 5.1 for Microsoft Windows® 95/98 and incorporated interactive video as a vehicle for providing contextualized advisement to learners. The simulation metaphor was a home remodeling project which required the learners to solve problems in geometry focusing on the concepts of volume and area of simple geometric shapes. As students worked through the problems presented in the simulation, they could seek advice from a “virtual aunt and uncle”. The student contacted the virtual aunt and uncle with a walkie-talkie which was presented as part of the simulation environment. When contacted, the aunt and uncle appeared in the simulation as interactive digital video of real-life actors composited onto the simulation environment. A set of possible enquiry topics was presented to the student in an on-screen text box. The student could select one or more of these topics. The aunt and uncle then discussed the enquiry topic by means of digital audio recordings of real actors.

An additional aspect of the simulation was the presence of a computer-generated character working in another part of the house and confronting the same geometry problems presented to the learners. The ability level, gender and ethnicity of this computer-generated character were selected by the student at the beginning of the simulation. The character appeared in the corner of the student's computer screen at random intervals during the problem-solving process displaying facial expressions conveying concentration or puzzlement. Occasionally the character spoke brief phrases aloud such as, "I think I've figured it out." The author's stated objective in adding the virtual character to the simulation was to provide the learner with a sense of competition.

The target population for this study was 7th and 8th grade students ranging in age from 12 to 15 years. From this population a sample of 123 students was selected from four middle schools in an American Gulf Coast city. Students were then randomly assigned to a control group or one of four treatment groups. All students were administered a 16-item survey which collected a range of demographic data including age, gender, computer experience, mathematics experience, game playing behavior, etc. A 23-item pretest was then administered to all students to verify that all participants possessed the basic mathematic skills necessary to address the problems presented in the simulation.

All five groups were evaluated on the same problems in geometry based on mathematics curriculum standards set out by the National Council of Teachers of Mathematics. Students in the control group were given a computer-based tutorial in which geometry concepts to be mastered were presented as word problems. This tutorial was not a simulation and did not incorporate graphics, animation or any form of contextual advisement other than straightforward help menus. Students in the four treatment groups were presented with the home remodeling simulation. The independent variables measured over the four treatment groups were as follows.

- Group 1, contextual advisement with competition.
- Group 2, contextual advisement without competition.
- Group 3, competition without contextual advisement.
- Group 4, no contextual advisement and no competition.

Treatment groups and the control group were administered a posttest in the form of a second simulation. In this instance, the metaphor for presentation of the geometry concepts was an indoor movie theater. Students were asked to solve the same types of geometry problems they had encountered in the home remodeling simulation, but in a different, more realistic context. The posttest simulation did not include elements of competition or contextual advisement. Upon completion of the posttest a 10-item questionnaire was administered to all students to acquire qualitative data regarding learning modality preferences and student attitudes about various aspects of the simulation.

Analysis of data indicated no significant increase in skills transfer for students in the treatment groups who used the home remodeling simulation with contextual advisement ($r = .111$, $p = .325$). Skills transfer as measured by pretest and posttest scores for the four treatment groups were as follows.

- Group 1, contextual advisement with competition, .47.
- Group 2, contextual advisement without competition, .82.
- Group 3, competition without contextual advisement, .78
- Group 4, no contextual advisement and no competition, .25.

The authors reported that a one-way ANOVA of all five groups did not yield a statistically significant difference between the control and treatment groups. Therefore, the authors' hypothesized outcome that contextual advisement and competition would promote skills transfer was not supported. At the same time, the authors did discover a significant interaction between competition and contextual advisement. Students in the treatment group with contextual advisement achieved greater skills transfer when competition was not present while students in the treatment group with competition performed better when contextual advisement was absent. This would seem to support the authors' hypothesis that competition interferes with effective learning and may inhibit attention, elaboration and metacognitive skills. While competition may be appropriate in some instructional situations (i.e., "educational games"), it does not appear to be a factor which contributes positively to learning in educational simulations (Alessi & Trollip, 2001).

This project seems to indicate that simulations can facilitate learning transfer in a classroom setting in which the simulation approximates a situated learning context. By removing the element of competition present in many traditional classroom activities, students were able to approximate a community of practice experience. The work of Van Eck and Dempsey (2002) lends support to the efficacy of simulations as a vehicle for delivery of situated learning experiences to the traditional classroom. The following two cases further address the use of simulations to facilitate classroom-based situated learning.

Middle School Earth Science – Astronomy and Geology

The effectiveness of educational simulations in science education is a topic of continuing debate in the literature. Jackson (1997) documented three case studies focusing on use of simulations in middle school astronomy and geology instruction. "Microcomputer and interactive video simulations can facilitate student learning in science by providing feedback about natural or technological phenomena which can be used to test hypotheses or models for scientific exploration and understanding" (Jackson, 1997). The simulations used in this study were all designed to address preliminary earth-science and astronomy topics appropriate to middle school science class.

The setting for this study was a public middle school located in a small urban environment in the Southeastern United States. At the time the study begin the middle school possessed extremely limited computing resources. All equipment and software used in the study were provided to the school through seed funding from the National Science Foundation-sponsored Statewide Systemic Imitative (SSI) project. Three science classes were selected for the study, ranging in size from 15 to 35 students with median and average class sizes of 28 and 27 respectively. Sample demographics, based on observation, indicated approximately equal distributions of males and families in all classes. The author was present and observed all class sessions discussed in the study, covering a two-day period. Although more than one student used the simulation software in each science class, the author chose to treat each class as a single case. Preliminary data for the study was collected from semi-structured interviews with the three teachers involved, student records, videotape recordings of typical class activities focusing on teacher-student interaction, and field notes taken by the author. Teachers were debriefed upon completion of classroom observations of students using the simulations.

From his field notes the author reproduced a number of informative comments from the instructors involved in the study. First, instructors noted that students demonstrated difficulty navigating the command and menu structures of the simulations. One instructor recommended that students be given adequate time to become familiar with the mechanism of the simulation software before attempting effective learning activities. Instructors also commented that students became easily lost in the simulation environment without timely guidance and supervision. All three instructors observed positive motivation aspects of the simulations in that most students became very enthusiastic about the material being taught.

The author drew two key conclusions which are supported by data collected during the study. First, simulations can motivate students to become actively involved in their own learning. Second, the positive instructional benefits of simulations can only be realized if students are guided and supervised throughout their exploration of the simulation. The presence of an instructor or coach, scaffolding and feedback are crucial for effective use of simulations in instructional settings.

This study would seem to reinforce two key aspects of simulations which are already well documented in the literature. First, simulations can motivate students to become more actively involved in their own learning similar to real-world learning experiences. Research has shown intrinsic motivation to be a key component of situated learning. Second, with appropriate planning, simulations can provide the kind of learner support common to situated learning settings. In the absence of these supports for learning, however, students may have a negative learning experience when using simulations. The final project presented continues the present discussion of simulations for teaching middle school earth science.

Middle School Earth Science – River Ecosystem

Dwyer and Lopez (2001) reported observations of elementary and middle school science students engaged in exploration of a river ecosystem using an educational simulation with integrated interactive video. The interactive video was used to realistically depict various aspects of the river ecosystem, including organisms and life cycle processes, with the goal of simulating a real-world setting. The authors evaluated the role of the simulation throughout all aspects of the learning cycle.

Participants in the study were 31 students selected from a private middle school science class, all of whom exhibited some form of documented learning disability. Data for the study was collected from three surveys developed and administered by the science teacher as well as comments from her daily journal. These surveys primarily measured student attitudes towards using computers. In addition, students were videotaped while using the simulation. Additional data were collected from debriefing sessions with students and the teacher, student field logs, student concept maps and outcomes from lesson activities.

Before using the simulation, all students were taught a lesson covering the basic science concepts presented in the simulation. To allow students to gain a degree of comfort with the simulation software, the first assignment consisted of a scavenger hunt in which students were asked to identify as many organisms as possible in the simulated river ecosystem. For the next assignment, students were asked to construct food chain models for specific organisms from the simulated river environment. Subsequent lessons became increasingly challenging requiring students to build and elaborate their knowledge base.

Based on observational and interview data collected during and after the study, the authors' stated hypothesis that simulation can provide "a meaningful learning experience for both the teacher and the students" (Dwyer & Lopez, 2001) seems to be supported. The teacher commented that the simulation allowed students to experience realistic problems involving many variables and arrive at realistic solutions in a relatively short time period. She also noted that, while using the simulation, students were motivated to build their own knowledge models and use them to solve problems. The authors concluded that simulations can significantly facilitate the learning of complex concepts from science and other technical domains in a real-world setting.

In this project we see once again that simulations can provide real-world learning experiences similar to that attainable in a situated learning setting. By addressing real-world problems with a wide array of variables students can experience the types of problem scenarios that situated learning contexts can provide. Further, students are motivated to become active learners when learning is situated in a specific context.

The three research projects presented here were selected to illustrate the potential of instructional simulations to provide real-world situated learning experiences in the traditional classroom. At the same time, these projects point to some of the problems that can arise when using technically sophisticated instructional technologies. Advantages to the learner of using these technologies have also been addressed. Further research in the form of simulation development and testing are essential for assessing the efficacy of these technologies.

Conclusion

This paper has presented a discussion of educational simulations as a methodology for providing some aspects of situated learning in the traditional classroom. The terms, educational simulation and situated learning have been defined with their respective advantages and limitations noted. Three research projects have been presented to demonstrate the use of educational simulations to facilitate situated learning in the classroom.

Van Eck and Dempsey (2002) reported on a simulation designed to facilitate transfer of mathematics skills from a learning context to a real-world scenario. The simulation incorporated interactive video as a vehicle for providing contextualized advisement to learners working through the simulation. Quantitative results reported by the authors were mixed and non-significant. However, their study did appear to indicate that simulations can provide some benefits of situated learning in the traditional classroom context.

Jackson (1997) documented three case studies focusing on use of simulations in middle school astronomy and geology instruction. Based on data collected during and after the study, the author concluded that the simulations had provided a meaningful learning experience for students and teachers. This project indicates that simulations can motivate learners when instruction is situated in a real-world context.

Dwyer and Lopez (2001) reported on elementary and middle school science students engaged in exploration of a river ecosystem using a simulation which incorporated interactive video. The authors concluded that simulations can provide a meaningful learning experience similar to that available in a situated learning context.

The design and assessment of educational simulations for situated learning is a relatively new area of study, but one which may hold substantive promise for learning. While innovative and intriguing research is currently ongoing, future research efforts should be focused on several specific areas. First, there is limited quantitative data on the efficacy of classroom use of educational simulations. Further studies need to be conducted using larger treatment and control groups. Data on the use of simulations specifically design to facilitate situated learning is limited further still. Second, the roles of feedback, coaching, scaffolding, learner control and debriefing in instructional simulations warrant further investigation. Finally, further quantitative study of the various simulation models and their support for specific situated learning strategies is necessary. As bandwidth gradually becomes less of a constraint for learners, educators can expand their utilization of instructional technologies like simulations. But without a clear understanding of how best to use these technologies, we have no assurances that they can make a positive contribution to instruction.

The benefits of “high-quality learning,” which simulations can provide to the student, are well documented in the literature (Forinash, & Wisman, September, 2001). However, further research is essential in ascertaining the instructional benefits of educational simulations as modalities for situated learning.

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