

FOSTERING SCIENCE EDUCATION OBJECTIVES WITH TEACHER-MADE COMPUTER GAMES

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ABSTRACT

The new generation of learners in today's schools is accustomed to a digital world. The students are surrounded by visual stimuli and are becoming proficient in areas not on the test! Their new ways of learning offer challenges to traditional teaching methods, and opportunities for creative use of their new skills and interests. In this mini-symposium we will give a brief overview of digital game-based learning, its philosophical and practical origins, values of play for general educational development as well as for science learning, and ways to approach the objectives of science education through use of games for teaching and learning. Values and types of educational games will be discussed, as well as general guidelines for development. Several Cyprus teachers have developed classroom learning games using computer technology. This paper culminates with their descriptions of how they constructed the learning devices for lessons on endangered species and introduced species.

KEYWORDS

Instructional games, science education, learning theory, game development

INTRODUCTION -SCHOOL'S MISMATCH WITH TODAY'S LEARNERS

"I never try to teach my students anything. I only try to create an environment in which they can learn."
---Albert Einstein

Albert Einstein's learner-centered approach would ring hollow to those teachers who struggle daily to be the information source who will help their students pass proficiency tests or raise the country's rank on international comparisons. These teachers (the majority of the teaching force) feel the need to pump out volumes of information for students to retain long enough to prove the school is doing its job, measured by the students' scoring well on some metric of factual learning. Likewise most parents have as a primary concern that their children compete well enough to be among the group selected for top schools and scholarships. Absorb much to compete well: is this the vision of education that will enlighten the world through another century?

Though small experiments in change are beginning to appear, in general schools throughout the world are still functioning on the "Tell and Test" model that has been prevalent for centuries. Pundits in the United States have made jokes that if a time traveler from 200 years ago were somehow transported to the 21st century, he would be amazed and uncomfortable with the changes everywhere, except in schools. The culture of "the sage on the stage," dispensing information and expecting it to turn into knowledge for the students, is a serious mismatch with modern student culture. We are trying to educate new generations in old ways, using tools that have ceased to be effective. Those who are delivering the content of education have a worthy goal, to get information to people, and they do their best using the tools that are comfortable to them. Traditional teaching styles, however, are mismatched with modern learning styles. The student boredom and low test scores we see from those methods should not surprise

us. Al Shanker, head of the American Federation of Teachers, claimed even in 1988 that "only 20-25% of students currently in school can learn effectively from traditional methods of teaching."

Students in schools today are unlikely to have ever seen a rotary dial telephone or a vinyl record of music that was not a CD. Many in U.S. high schools have never lived in a home without a computer. College students bring their assignments into the computer lab on a key ring fob that holds a gigabyte of memory, and their mobile phone allows them wireless access to the vast resources of the internet from their seat in the stadium. Bruce Springsteen is telling them, "We learn more from a three-minute record, baby, than we ever learned in school" (quoted in Prensky, 2001). Seymour Papert, developer of LOGO, was not optimistic about the impact his software might have, writing that "Putting a computer in a classroom is like strapping a jet engine on a stagecoach" (cited in Tapscott, 1998).

REFOCUSING EDUCATION METHODS

Our students have new skills. As William Gibson, noted modern author on the internet culture, has said, "The future has arrived; it's just not evenly distributed." McFarlane (1997) eloquently discourses on the values of computers in primary school, reviewing the extent of change in the teacher-pupil dynamic but holding forth optimistic views on the ability of schools (through young teachers interacting with technology-literate children) to ultimately gain the promised benefits. She is especially critical of testing programs in the current culture: When students have instant access to information, what is the value of memorization? We teach skills but assess facts. "The ability to find, interpret and evaluate information is far more important, as are the skills relating to problem-solving and critical thinking" (p.3).

Marc Prensky, author of *Digital Game-Based Learning* (2001), claims that "within most of our lifetimes learning will become truly learner-centered and fun! The reason this will happen, and happen soon, is that learners will demand it" (p.15). Prensky does not imply that students will have an easy life. Learning will still be hard work because effort will still be needed. It is just that the work part will not feel onerous because it can be fun.

The value of play as part of learning would be echoed by key voices from education and communication. John Dewey (1910) defined play as an activity without a goal, while work was goal oriented. The "natural desirability of work," however, was undermined and became a drudgery when there was unrelieved emphasis on the goal (the test?). "Such hateful work was met with revulsion, shirking and evasion. This was especially visible when children were coerced into drudgery in the classroom" (cited in Deegan, 1999).

Jerome Bruner (1976) saw play as fundamental to human learning. Humans, with their long immature period as organisms, have much time to play and to safely try novel approaches to situations, clearly a form of exploratory learning and an advantage in adult survival. Exploring through play tasks was seen as much more effective than closed learning tasks (with correct answers) as a way to learn problem solving. Thus play is seen as a context for learning, developing intellectual skills and processes in a low-threat environment (Whitebread, 1997).

One of the key requirements of the technology-literate students we now face in classrooms is the demand for an active learning environment. Scenes must change quickly, be colorful, be interesting, and involve the learner in the action. This is not an issue only in primary schools. Content-heavy and problem-based courses of study like medicine, engineering, and business are exploring media and methods that look at least as much like entertainment as like learning, and are more acceptable for the image. Readers are directed to the medical school game for reviewing content in pulmonary physiology, "Who wants to be a Physician?" (Moy, Rodenbaugh, Collins and DiCarlo, 2000), and the teamwork fostering exercises for journalism students (Swegle, 2001-2002). As one of the physiology students commented during game evaluation, "The best teaching tools are those which make you feel like they aren't teaching tools" (Moy, et al, 2000, p. 36).

Social involvement is also a requirement in new "edutainment" media, so the "lifelines" in the physiology game and the team building in journalism are on target for appropriate development. These examples and many more on the Internet demonstrate that computer use is not the lonely activity it was once perceived to be. One has only to observe the popularity of on-line adventure games like EverQuest to see that the technology is able to offer social stimulus. When we involve groups of students in managing the life forms in SimEarth we are using the social aspects, the problem solving, and the intellectual challenges that bring the best from the digital to the academic world. Perhaps we are finally coming to see what Marshall McLuhan meant when he said "Anyone who makes a distinction between games and education clearly does not know the first thing about either one" (McLuhan and Fiore, 1968, reprinted 1997).

SCIENCE EDUCATION OBJECTIVES MATCH GAME OBJECTIVES

To embrace educational games as a valid instructional tool, we must be convinced that they can meet the objectives of education as well as make schooling fun. In Greek, the words child and play (=play a game, when expressed by a child) have a common root/origin (child = pedi, play = pezo). Think about what games do, and then think about what has to happen in science class. What are science education's objectives for learners at all levels? Each educator has a personal list that includes such things as providing opportunities to

- Think critically
- Learn and practice methods of inquiry
- Develop science concepts that facilitate understanding of the students' physical and biological environment
- Develop scientific habits of mind (willingness to subject ideas to testing, multiple working hypotheses, etc)
- Develop scientific attitudes (curiosity, inventiveness, ability to accept uncertainty)
- (Lemlech, 1998)

To this list we might add *problem-solving ability* as a desired outcome for science education. Whitebread (1997) maintains that educational games can develop the significant skill sets by

- Encouraging a playful approach to learning (non-threatening scenarios)
- Placing science problems in a meaningful context (such as in role play and simulations)
- Stimulating collaborative work and discussion as solutions are sought.

Thus the social aspects return to our thinking: collaborative/cooperative learning is a science education methodology that is actively pursued but rarely rewarded in the current assessments that are shared internationally. One of the goals for students in the Cyprus Science curriculum for Primary Education is: "To cooperate with other students of their group in order to carry out their work." We teach students competition instead of cooperation, then we wonder why cheating occurs on tests and why wars erupt in the evening news. The U.S. Department of Labor has identified *ability to work cooperatively* as one of the major skills needed for the work force of the 21st century. Other skills noted by the Department of Labor might be developed from games as well:

- Problem-finding (what is really the root of the issue, a precursor to problem-solving)
- Ability to find information, including with computers
- Ability to use a variety of communication methods. (Secretary's Commission, 1994).

Constructivist learning is another process that effective science education can foster. From the moment of birth we are building cognitive networks with each experience. Each thing we do, each fact we learn, is compared against the existing framework of ideas and either incorporated, rejected as useless, or stored away for possible later use, much as teachers consciously collect materials for instruction. Science learning can be acquired as isolated facts, with the learner left to determine the utility, or it can be presented in meaningful contexts that make connections to prior learning more obvious. Digital games based on science topics can illustrate relationships among the disciplines and within the subject areas. Students can try out ideas in safe environments, and can observe dimensions of space much more

distant and large or gain a close-up into the microscopic world. Games allow them to insert themselves into science processes, expanding their understanding of what is happening and how humans relate to science and environment. As children grow in experience, the digital world may assist their assimilation of ideas and connections, just as pages of Internet sites or slides of Powerpoint are linked in logical sequences.

Integration of sciences is another objective favored by new curriculum reform efforts. Rather than let one science discipline end when the class period or the marking period is over, students need to see that one science cannot realistically be studied to the exclusion of others. Games that involve systems, such as SimCity and SimEarth, or that use role play on decisions to be made using science information, demonstrate dramatically how the sciences are linked. Issue-based games about the environment are particularly useful in this regard. Frequently students are led to seek new information for game completion, or as a result of the game, and knowledge selected on a need-to-know basis is quickly added into constructivist frameworks.

For science education, then, educational games represent the convergence of strategic national needs, learning theory, technology, entertainment, and motivational theory. How can teachers take advantage of such a far-reaching opportunity?

GAMES FOR SCIENCE LEARNING, COMPUTER STYLE

Games are not the answer to every educational need, but judicious use of them can enliven the science classroom and meet science education objectives. Is a particular science lesson appropriate for teaching with a game? Prensky (2001) has identified a number of game types and the objectives that might be accomplished by each type. His original chart has been modified for classroom science education here:

"Content"	Examples	Learning activities	Possible game styles
Facts	Who wants to be a Organism ID Environmental laws	Questions, Identification, Drill, Association, Memorization	Game show Flashcard games Sports games
Skills	Interviewing, using computer software, Survivor skills	Continuous practice, increasing challenge, imitation, feedback	Role-play Adventure games Detective games
Judgement	Decision making Ethical conduct Environmental choices Data analysis	Review cases Ask questions Make choices	Role-play Detective games Adventure games Strategy games
Behaviors	Making laws/policy, Setting examples	Imitation, feedback, practice, timing	Role-play
Theories	Cause and effect Human vs. natural impacts, change	Logic Experimentation Reasoning	Open-end simulation Building games Reality testing games
Reasoning	Strategic thinking, Problem solving	Problems Examples, alternatives	Puzzles Mysteries
Process	Biological processes Construct molecules Solve mystery	System analysis Find/use tools Apply information	Strategy games Adventure games Simulation games
Procedures	Dissection, use of taxonomic key,	Recognition of parts Graduated tasks	Timed games Simulations
Creativity	Pollution prevention devices, underwater cities, space travel	Think outside the bowl! Play, apply reality to fantasy situation	Puzzles Invention games Building games
Systems	Cities, ant farms, world ecosystems	Understanding principles Playing in microworlds	Simulation games

Communication	Involvement in decision making	Appropriate language, timing, feedback	Role play
Observation	Adult/immature animal forms Landform study	Observing, Inference, Feedback Comparison	Concentration games Adventure games Matching games

(adapted from Prensky, 2001, p. 156)

Once the decision has been made to develop a game, and appropriate technology is available, experts recommend the following steps in development (combined from Prensky, 2001; Lemlech, 1998; Fortner, 1988; Smith, 1976):

1. Specify the grade level of the learners who are to play the game.
2. Identify instructional objectives of the game and determine if a game is the most appropriate instructional tool.
3. Identify the key subject matter to be the focus of the game, and develop a concept map of the science interactions involved.
4. Choose the kind of game you will develop (see the adapted Prensky chart for ideas based on objectives)
5. Determine if the game is for the whole class or small groups.
6. Set the situation and conditions. How much reality is involved? Do you need references or time for student Internet searches? What equipment do you have available?
7. What is the currency of play? Do students win points, exchange play money, or make decisions that determine losses and gains?
8. Identify the end point. When will the game be over? Are there winners and losers?
9. Decide on rules to govern play, including a time limit if needed.
10. Plan how to introduce the subject matter and rationale for the game so that it will be taken seriously as a learning experience.

The teacher's role, even if the game has been developed by someone else, includes these critical activities:

- *Preparation.* The class must be ready in terms of background skills and information, and awareness of the reason for the game. All materials must be ready in the appropriate amounts. Technology must be checked for software compatibility, access to equipment, and appropriateness for student skills.
- *Observation.* Determine the level of involvement of all students and be prepared to make adaptations in the rules or methods to allow as much interaction as possible. Be sure learners are using the experience for learning and not just for recreation.
- *Debriefing and discussion.* A must for following up any educational game is to assure that students have gained from it the desired information and insights. This is not to say that a lecture will follow to get all that content delivered! Students will quickly detect the source of the information they seek, and if it is to be the teacher after all, time spent on a game is wasted.

If assessment of learning is planned, it should not be in the form of a test! One method the authors have used is to have students construct a concept map of the main ideas of the game. Since the games have started with a concept map, this is a good way to check for congruence of learning with the developer's content goals. Few of the published reports of games in education literature have been specifically evaluated for learning goals. Moy, et al (2000) is an exception, with an excellent report of a substantive follow up survey among the medical students. Participants enjoyed the game and felt they learned more from it than standard review methods, but wanted multiple choice questions so the game would move faster and more could participate. A strength of that "Who wants to be..." game was that the lifelines were other students who had to pay attention and think along with the contestants, for they could be called on at any time to help their friends: to provide the answer, give a hint, or vote on the answer given by the contestant.

Other types of evaluations have been even more indicative of learning effectiveness than these self-reports. Lightspan (2000) supported an academic evaluation of its learning games in over 400 schools. Meta-analysis showed that scores on standardized tests were higher for those who used Lightspan. For every 100 students in the control group who scored above the 50th percentile, 128 Lightspan students achieved such a score. [Lightspan offers considerable amounts of teacher training in several curriculum areas to accompany the use of its software.] On the medical education front, Click Health, a company that helps children manage their own asthma and diabetes, did clinical studies with support from the National (U.S.) Institutes of Health. They found that urgent doctor calls among the treatment group declined 77%, and children's communication with their parents about their condition increased.

For teacher made games, we recommend with Smith (1976) that a structured or observational evaluation should be done during and after play to answer questions about

- Whether the game is valid (does it accomplish the educational objectives for which it was constructed, how much learning takes place);
- How well the game covers its subject matter (is it accurate, is enough information provided, does it represent its subject well);
- The game's comprehensibility (do players understand the game and its operation, is it a complete picture of its subject);
- How well the game is structured (does it have reasonable and understandable rules);
- To what extent are players participating (are some left out while others play, do some get bored and drop out, do players have fun while they are learning).

These questions, along with the construction of a concept map for games that are based on subject matter interrelationships, can provide information for improvement of future attempts at digital game-based learning.

TEACHER-MADE DIGITAL GAMES: FOUR EXAMPLES

1. A game for rewarding knowledge about an endangered species. From the table of game types, this one deals with facts in a game show format.

Who wants to be a Flamingonaire?

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Many advantages have been mentioned in favour of using games in education. Games make learning more attractive and interesting. Games are inherently different from other school activities and are welcomed by populations that have not succeeded in various school subjects. Games are uniquely successful for getting and holding the students' attention.

The well-known and popular TV game "Who wants to be a Millionaire" was altered to assist primary students in learning about flamingos, a migrating bird which is protected in Cyprus, and Lake Aliko, a lake where flamingos stay for the winter. Educationally, the subject matter has value because it is relevant to Cyprus students, it concerns a species that is threatened by a number of natural and human-caused factors, and preservation of the biological resource requires attention to factors that are affecting the air, water and land as well. Thus a study of flamingos integrates the sciences and helps students see how Earth works as a system. The game was given the name: "Who wants to be a Flamingonaire?" It is an online interactive activity in which students are "forced" to find all 15 correct answers using the inquiry method.

The design of the "Who wants to be a Flamingonaire?" game was done with two software programs: Swish, a user friendly program that makes Macromedia Flash animations, and the HTML editor that is offered with the Mozilla browser. The game follows the same rules and plays the same music as the original TV game, with some exceptions. The player must answer correctly all 15 questions. All questions are of multiple-choice type, with four possible answers, and the questions are hierarchically ordered according to their difficulty. If a wrong answer is given, the game stops. Fortunately, the player

is then given the choice to start again, an opportunity that is not instantly available in the original TV game. This sounds very difficult, particularly for primary school students who are the target audience. For this reason, the player can get help for each question, instead of the three common helps that are offered in the TV game. When the button “help” is pressed, the player can see an authentic text, a map or some pictures. The correct answer is found in the information given. Because the text was from original sources, some words thought to be unfamiliar to students were explained at the end of the text.

A major objective in the design of this game was to be simple. If one knows the rules of the original TV game, then he/she can play the “Who wants to be a Flamingonaire?” game without any additional explanations. The game can be used in a variety of ways ranging from the beginning of a new unit, as an introduction, as a culminating activity, or as an evaluation material. It can be played by a single player or by a group of students working cooperatively.

2. A game for skill development in observing how a rare endemic species is similar to and different from a common domesticated animal:

Moufflon

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Educational games have a number of advantages for learning environments. Primarily, they can effectively motivate learners to study material they might not otherwise choose to study at all. Moreover, learners will spend more time with the program than they would if it did not use the game background. Finally, through games, learning becomes more enjoyable and more than something we are required to do. Some games facilitate competition and teamwork, and others contribute to the integration of knowledge and skills across a number of content areas. This paper describes the development of an educational game for elementary school. It presents the relationship of the *moufflon* (an endemic, endangered, reddish-brown wild sheep of Cyprus) and the domestic sheep of Cyprus (*Chios sheep*) using simple computer technology.

The first important step in the development of an educational game is the collection of data relevant to the topic. To find such information I (a) conducted several interviews of officials of the Game Service, the Agricultural Research Institute and the Ministry of Agriculture, Natural Resources and the Environment and (b) collected scientific articles, brochures, internet resources etc. Then I constructed a concept map concerning moufflon and its relationship with domestic sheep. The concept map included all the relevant topic information and the way the facts are connected. A Powerpoint presentation under the topic “Two animals of Cyprus” was the third step to the whole procedure. I suggest that students run the Powerpoint presentation, then have a class discussion about what they saw. This gives them the information to finally play a role game (debate), which will lead to the “First Pancyprian Conference concerning the indigenous species of Cyprus.”

I used Powerpoint because though it is not interactive, it is colorful, it provides for movement of the scenes, and the discussion between the two species makes students think that they indeed talked to sheep and moufflon.

3. A game of reasoning and role playing in groups to examine threats to a rare species:

A computer-based role-play board game: Protect the Griffon Vulture

Marios Papaevripidou, Learning in Physics Group, University of Cyprus

Integrated curriculum provides great opportunities for students to develop multiple reasoning skills and conceptual understanding. The way the different subject areas are connected and interconnected in an integrated curriculum base enables educators to organize fruitful and challenging teaching environments, which are undoubtedly attractive for all children. In order to fulfill this educational demand, we designed an interactive computer-based collaborative role-play game to help children

investigate the factors that affect the survival of the Griffon Vulture in Cyprus. The Griffon Vulture issue was ideal for integrating different subject areas of the curriculum, such as Natural Sciences, Environmental Science, Geography, Mathematics, Language, History, etc. The role-play activities as well as the game board were designed with Microsoft PowerPoint Software, which enabled us to present and animate useful information about the bird.

Children in an upper elementary grade classroom are divided into five groups, each consisting of a shepherd, a tourist, a road construction worker, a hunter and a rabbitry – hennery owner. All identical role players from each group gather at one of the five computers of the classroom and study carefully the information concerning their role from a *.ppt file. They become experts on what their role involves. After that, children meet with their initial groups and explain to the members of their group whether they (as role players) contribute to the extinction of the Griffon Vulture. The discussion is very useful, because children will gather information about how people from all the roles affect the vulture's future. Each group of children with the five different roles then goes to a computer and opens the file labelled “game board.” The game is entitled “The Vulture Game” and it consists of a path of steps. In order to move a number of steps ahead, children have to cooperate with their group to select the correct answer out of four possible answers on a given question. If they fail to find the correct answer, the game asks them to move a number of steps backwards. Going backward will cause their group to lose valuable time, and the object of the game is to finish first (demonstrate the most knowledge about factors affecting the Griffon Vulture). The acquired knowledge from the instruction is assessed through the construction of a concept map in Kids’ Inspiration software.

4. A game of judgement with a mock court:

The Tree Court Investigation

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The Tree Court Investigation is an online interactive activity. It engages elementary students in a role game the main focus of which is to promote meaningful learning through web-based inquiry. Another goal of the game is the development of students’ argumentation skills.

The game deals with the issue of exotic tree species in Cyprus. Two of the most widespread exotic trees in Cyprus are *Eucalyptus camadulensis* and *Acacia cyanophilla*, both introduced by the British in the eighteenth century. Students are asked to become the judge or the attorney in a tree case and support or oppose a particular citizen's decision to plant a certain tree. In order to build their arguments students need to investigate the factors that should affect a citizen’s decision in choosing the appropriate trees for planting. Their investigation is guided by an interactive hypermedia application made with Macromedia Flash. Through the application students have access to various web resources that they can use to investigate and gather evidence to support their arguments. Resources vary depending on the form and the source of information they provide. Students’ final arguments are evaluated according to the source of the evidence that support them.

The application provides a platform that guides investigation in a contemporary environmental issue. The web and its hypermedia capabilities can give new meaning to inquiry by a) providing an enticing environment, b) giving access to real-life resources of scientific data and c) facilitating inquiry making it possible through a unified environment. Learning activities that employ web inquiry as an avenue for solving real life problems can make the most of the above features of the web.

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