THE APPLICATION OF DIGITAL GAME-BASED LEARNING TECHNIQUES IN TEACHING EARTH SCIENCES LABORATORIES

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Abstract

The goal of this study is to develop and enhance teaching earth sciences basic courses for undergraduates at universities. This method will help to improve learning and to move the student/ teacher interaction to higher levels.

In this paper, we introduced earth sciences visualization classification as framework for geosciences e-learning. Earth sciences learning domains have been classified and visualized in the following six main domains: 1- Time domain represents the past, recent and future forecasted geologic events. The time domain is dealing with geologic events that happened millions of years ago and their components and environments do not exist any more, or currently happening or those expected to happen in the future under certain environmental conditions. 2- Speed domain can be either very slow geologic events or very fast geologic events. The speed domain is dealing with slow geologic events like continental drift, oil and water migration and fast geologic events like earthquakes, subsidence and some geochemical reactions 3- Size domain can be presented with very small (microscopic) geologic features, and very large (regional) geologic features. This domain is very difficult to visualize because we need either very high magnification for the very small objects or a very regional look from the space to the earth. 4- Hidden domain in the earth sciences is mainly related to the sub-surface geologic features like hydrogeology, petroleum geology and sub-surface stratigraphy. 5- Imaginary domain is related to those essential parameters that need to be visualized all the time to identify mineral types and structural relationships. These parameters are the crystallographic and optical axes and angles. 6- Analytical domain is induced data, concepts and parameters for specific area, model or problem. This domain can visualize through geochemical, geophysical, and mathematical analysis.

Our challenge in this study is to use games to engage the earth sciences student in the earth sciences world, taking in consideration the main structural elements of games: 1- rules, 2- goals and objectives, 3- outcomes and feedback, 4- conflict/ competition/ challenge/ opposition, 5- interaction, and 6- representation or story.

Two applications have been developed in this study to identify rock samples and to demonstrate the mechanism of major geologic processes.

Keywords: Virtual laboratory; e-learning; Game technology, earth sciences, geology.

1. Introduction and background

Computer and video games are potentially the most engaging activity in the history of mankind. Games give us enjoyment and pleasure. People rarely succeed unless they have fun in what they are doing. Play is our brain's favorite way of learning. People who perform very playful tasks enjoy what they are doing.

In this study the Geology Virtual Labs (GVL) are developed in the perspective of game-based technology. With these fast technological advancements, new methods of teaching have to be developed to boost the traditional instruction paradigms. Geological sciences have been mainly taught with conventional educational tools, textbooks, lectures, and laboratories. With the latest virtual labs technologies, learning media can supply geological information to the students, provide attractive instruction with electronic media, and promote their technology proficiencies, all causative to their professional improvement. GVL teaching material is slowly being developed and there is a strong need for new tools in earth sciences because of the difficulties in learning and visualizing in many of their concepts. Most conventional teaching materials are linear and static which makes earth sciences harder to teach, since the content is dynamic, with time and causal relationships. Thus, regardless of the instructor, students have struggled to generate correct mental models of the concepts. The dynamic nature of the topic should be taught with an analogous teaching approach.

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In the earth sciences, we are dealing with events that had happened millions of years ago with creatures and plants that don't exist any more. Earth sciences studies are mystic in nature. Geologists can be imagined looking for treasures, precious metals, oil and gemstones. Adventure is everywhere far in the deserts and deep in the oceans or very high on the mountain tops. It can be even inside the earth. Virtual realities are the right tool to teach earth sciences topics to help students imagine the concepts that will never have the opportunity to see them take place. The quality and effectiveness of this study depend on multidisciplinary capabilities of scientific and educational advisory, animation and software designing, content developing, and evaluation. GVL are interactive and potentially high on the inquiry scale. The GVL can be used in a more formal educational setting as supplemental material to prepare for, or reinforce a conventional geologic lab, or even to provide a lab-like experience when a geologic lab is not possible. The GVL are useful for revealing science as a process and for carrying a learner through that process while treating concepts and methods/technology together.

The current study is a product of the Geology Virtual Labs development. The heart of the present study is an immersive, interactive learning environment designed to teach most earth sciences topics using a high level of integrated visual teaching. In this paper, the educational design and methodologies will be described and then an evaluation of the system will be shown. It is a suite of customizable and interactive teaching media designed to integrate and dynamically instruct complex systems using media-rich animations, real-time simulations, and virtual environments. It is a system that has been developed, implemented, and then evaluated for its effectiveness of learning outcomes.

2. The need to Virtual labs for Earth Sciences teaching

The virtual reality attributes can be affected both by the type of system used, input devices, etc. and the virtual environment by what it presented in the 3D environment. With the development of new computer technologies, it is now possible to simulate earth science laboratory projects on a computer. It will be possible to offer students "virtual laboratories" via the WWW or CD-ROM. Experiment-oriented problems can be presented without the overhead incurred when maintaining a full laboratory. Virtual laboratory is not viewed as a replacement for, or a competitor with, a real laboratory. Instead, virtual laboratories are possible extensions to real laboratories and open new opportunities not viable entirely within a real laboratory at an affordable cost. Virtual Environments applications have been developed to visualize molecular bonding (Byrne & Furness, 1994), photosynthesis (Nikolou, Mikropoulos, & Katsikis, 1997), elecromagnetism (Salzman, Dede, Loftin, & Sprague, 1997), the inner-working of a factory (Wilson, Cobb, D'Cruz, & Eastgate, 1996). These types of Virtual Environments not only allow concepts and phenomena to be visualized and manipulated, they also allow different perspectives to be taken. Virtual Environments are safe environments for exploration and allow students to experiment with trial and error learning strategies without negative implications (Figs. 1, 2, 3 & 4).

In this study, the earth sciences learning domains can be classified and visualized in the following six main domains (Table 1):

1- Time domain
    - a- Past geologic events
    - b- Recent geologic events
    - c- Future forecasted geologic events
2- Speed domain
    - a- Very slow geologic events
    - b- Very fast geologic events
3- Size domain
    - a- Very small (microscopic) geologic features
    - b- Very large (regional) geologic features
4- Hidden domain
    - a- Sub-surface geologic features
5- Imaginary domain
    - a- Crystallographic parameters
    - b- Optical parameters
6- Analytical domain
    - a- Geochemical analysis
    - b- Geophysical analysis
    - c- Mathematical analysis

Table 1. Main Types of Earth Science Learning Domains

Domains	Some Domain component	Examples	Learning Activity	Possible Game style
<u>**Time Domain**</u>				
Past events	- Movements - Environment - Fossils	- Mountain Building and continental drift - Different environment during the geology Eras - Plant and animal fossils	Problems Examples	Puzzles Simulation games
Recent rare events	- Natural hazards	- Volcanic and earthquakes	System analysis, and reconstruction	Adventure games, Simulation games
Future Forecasted events	- movements - Environment	- Shorelines - Change in environment	Logic, Experimentation Questioning	Open ended simulation games, building games Construction games, Reality testing games.
<u>**Imaginary Domain**</u>				
Imaginary Parameters	- Crystallographic axis - Optic axis	- Rotation visualization - Measuring angles and signs	Imitation, Feedback, coaching continuous practice, Increasing challenge	Adventure games Detective games Role-play games
<u>**Size Domain**</u>				
Microscopic	- Objects in millimeters and micro-millimeters	- visualization for micro-millimeters features (composition and structures)	imitation practice	Flash card games Detective games
Regional	- Mountain chains, Continents Oceans	- visualization for mega-features (composition and structure)	imitation practice	Flash card games Detective games
<u>**Hidden Domain**</u>				
Sub-surface	- Groundwater - Petroleum	- groundwater exploration and pollution - petroleum exploration	Understanding principles Graduated task	Simulation games Puzzles
<u>**Speed Domain**</u>				
Very slow events	- Movement - Geochemical changes	- continental drift - crystal growth, alteration	observing, Feedback	Concentration games, Adventure games
Very fast events	- Movement - Geochemical changes	- Volcanisms, earthquakes and subsidence - Strong chemical reactions	Observing Feedback	Concentration game, Adventure games
<u>**Analytical Domain**</u>				
Geologic Analysis	- Instrumental - Outputs	- Geochemical analysis - Geophysical analysis - Mathematical analysis	System analysis and demonstration practice	Strategy games Adventure games Simulation games

2.1 The Time Domain:

According to the time domain, the past, present and future geologic forecasted events are presented. The virtual reality technology can help in rebuilding and visualizing environments that we can never actually experience, either in the past or the future, and it can help us to interact with fossils in their ancient habitat.

2.2 The Speed Domain:

The speed domain represents the very slow and the very fast geologic events, which are beyond the human capability to observe them without using precise measuring instruments. With virtual reality technology we can readjust the speed to be able to visualize study and interact in this environment. Known examples in the speed domain are the very low speed of continental drift and ocean floor spreading, and the very high speed volcanic eruptions and earthquakes.

2.3 The Size Domain:

In the size domain we need advance technology to see it. Satellites or airplanes are needed to capture regional features or high precision microscopes to examine very small geologic features. These capabilities are available only for small sector of geologists and with somehow a high cost. The virtual labs will help simulate and emulate this geologic feature and will make it available to the majority at very low cost.

2.4 The Hidden Domain:

The Hidden domain is represented by sub-surface geologic features. It is hidden because till now we do not have the technology to deal with it in a direct way to visualize the sub-surface. This information is used to be collect through drilling deep wells or using geophysical techniques as an indirect way to observe this domain using its physical characteristics (e.g. waves and signals). The virtual reality will help us visualize, interact and move freely in this domain. That will speed up and support the student learning capability in this field of knowledge.

2.5 The Imaginary Domain:

The imaginary crystallographic and optical parameters are the infrastructure of the crystallography and optical mineralogy (Fig.3). Because they are imaginary parameters, they take too much effort for the student to get it, and usually there are hazy topics that will still need more imaginary efforts that some students cannot succeed to make it. The virtual reality will meet the student half way to let him visualize the axis, the angles and their relation with other parameters like interference color or cleavage planes etc.

2.6 The Analytical Domain:

Thanks for the virtual environment, this technology is already helping a wide sectors of researchers in visualizing the distribution and the behavior of geochemical, geophysical and mathematical data a help us see it in different perspectives and compare it with other outputs. The virtual reality also gives us the freedom to navigate inside a three dimensional analytical domain to enhance the ability for better interpretation.

3. Materials and methods

Our objective of this study was to develop interactive media-rich game based teaching modules in basic earth sciences courses for the undergraduate level. Our endeavor is to use the power of games *to engage us in the earth sciences world,* drawing us in, often in spite of ourselves. This powerful force stems first from the fact that they are a form of fun and play, and taking in consideration the main structural elements of games (Prensky 2001):

1- Rules, 2- Goals and Objectives, 3- Outcomes and Feedback, 4- Conflict/Competition/Challenge/ Opposition, 5- Interaction, 6- Representation or Story. Let us discuss how and why these factors they lead to such strong engagement in our geologic studies.

3.1 Rules are what differentiate games from other kinds of play. Rules impose limits. They force us to take specific paths to reach goals and make sure that all players take the same paths. Student focus groups and interviews with faculty directed us to the conceptually difficult content areas. Geological difficult concepts were sorted into their respective teaching module category: past geologic events, recent rare geologic events, Future forecasted events, topic related to imaginary parameters, topic related to microscopic objects, topic related to sub-surface investigation, very slow geologic events, very fast geologic events, and geological analysis.

Rules design strategies and protocols established in the current model can be reused to facilitate further content development. Below is the general iterative design strategy for approaching (educational media) development (Cooper 1995, Shneiderman 1997, and Neilsen 1994).
a. Investigate and understand. In order to design for the student we have to identify who they are, what their requirements are, and supply motivational factors-all based on the user's background.
b. Define the problem. Establishing the rules for instruction provides a framework for designing the geosciences curriculum and learning activities: content, organization, captivating the student. A designer must also be a teacher. When presenting the information, the designer must not only employ their knowledge of learning theory, information design, and human communication, but also have a solid understanding and interpretation of the content. For example: In case of past geologic events. This category deals with mountain building, continental drift, the different environment during the geologic Eras with their plant and animal fossils. Puzzle and simulation game style is recommended with rules designed for problems with examples as learning activities. In case of applications dealing with imaginary parameters, they are used in crystallography, crystal optics and mineralogy. This category deals with properties comparison, measuring angles and sign. Adventure, detective and flash card games are recommended with rules supporting imitation, feedback, coaching, and continuous practice and increasing challenge as learning activities.

3.2 Goals or objectives The goal is often stated at the beginning of the rules. The goal is to get the highest score, to reach the end, to capture a trophy and so on.

3.3 Outcomes and feedback are how progress can be measured against the goals. Feedback comes when something in the game changes in response to what you do-it is what we mean when we say computers and computer games are *interactive*. Feedback comes in the form of a numerical score, but it can also come in many other forms as well.

3.4 Conflict, competition, challenge, and opposition are the problems in a game the user are trying to solve. It can be a geologic puzzle to solve, or anything that stands in the way of your progress. Conflict/ competition/ challenge or opposition is what gets the player's adrenaline and creative juices flowing, and what makes him excited about playing the game.

3.5 Interaction has two important aspects: The first is the interaction of the player and the computer. The second, though, is the inherently *social* aspect of games-you do them with other people. Play promotes the formation of social groupings. While you can play alone, it is much more fun to play with others. That will help support the social aspect in earth science community which will lead to more creative ideas in this area.

3.6 Representation means is the essence of what makes a game, while some think it is just the "candy" around the game. We have to put in our consideration that - 80% of game users are mainly interested in content and 15% are influenced by design and graphics. Storyboarding is a primary development step that scripts the events on a page. Design concepts can be tested in an initial prototype for flaws before investing costly resources. The key emphasis is student-centric design for the user and not the designer or instructor, make the content meaningful and applicable to engage the user, and let them control outcomes with simulations and games. Working in a million year ago environment, underground, or in a highly magnified world will produce a very interesting representation but controlling some of the attributes in this world we make the student engage and contribute in the relevancy of the virtual lab.

4. Technical development

During the initial phases of this study, different evaluation techniques for the set-up, development, and delivery of Virtual Labs were evaluated. The goal was to establish database-style architecture for archiving usage data and CDROM delivery for easy dispersion. The following applications, platforms, and environments were chosen:
- Conitec, 3-D GameStudio A6 (Professional Edition).
- Newtek, LightWave 3-D Animation.

Currently, our primary mode of delivery is with CDROM executables.

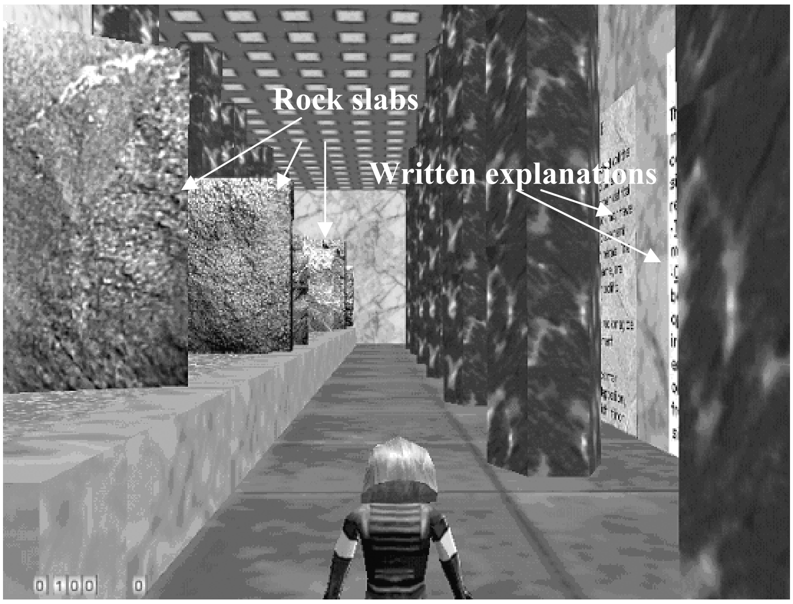

Fig.1. 3-D animated rock slabs models (left side) and written explanations (right side) with voice description.

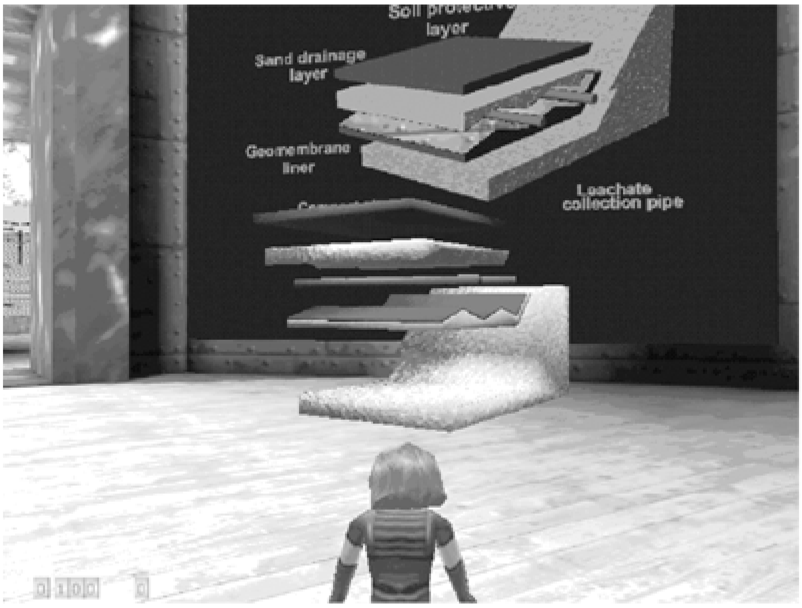

Fig.2. 3-D animated landfill mechanical model with voice description and graph describing the main components in order of formation.

5. Evaluation

The earth sciences schools endures from some deficiencies especially in areas related to e-learning, and the reason the fast change in technology and the great need for continuous funding to keep on going in this fast track of learning. Most students are already familiar with game technology and web-based interaction. About 80% of these students got there own access to personal computer and the rest use the available capability on campus. The current virtual lab played a vital role in providing low cost reliable dynamic three dimensional colored interactive illustrations through a free CD during the geology basic courses.

Evaluation of the program has been conducted using surveys (Neilsen 1999 and Neilsen 1994), focus groups, interviews, and a back office designed for user-tracking. The earth sciences basic core courses have been using the geologic virtual lab for the past year. The following are examples of the evaluations questions that reflect the condition of our students, teachers and the university.

How Game-based learning techniques be used to enrich and enhance earth science student learning?
How do we create inspiring and significant learning models for the student?
What aspects of the earth sciences learning are appropriate for interactive learning tools?
How should Game-based learning tools be used in the earth science curriculum?
What is the best execution method?

Student feedback is essential to guiding future directions of this assignment. The students' feedback shows that its acceptance and usage has been increasingly more successful with the addition of relevant course content and ongoing integration with related course material. As a result, students have found it to be an enormous asset to the class.

Fig.3. 3-D animated rhombic dodecahedron crystal models showing three tetrad, six diad, four triad axes and nine planes of symmetry with voice description. Note: axes of symmetry to the left and planes of symmetry to the right.

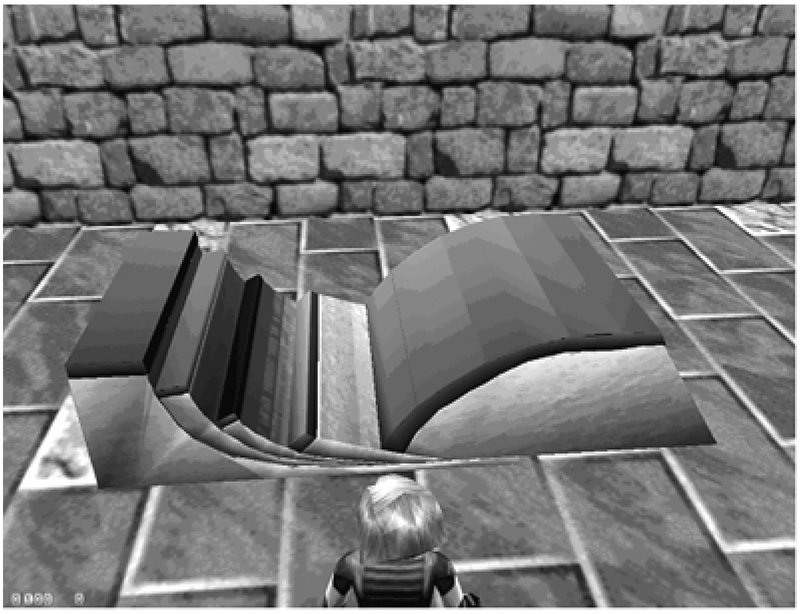

Fig.4. 3-D animated mechanical model of imbricate listric normal faulting with rollover associated with voice description.

6. Summary and Conclusion

"The present is the key of the past" is the main principle in studying earth sciences. Too many imaginations are needed to make good geologist. The crystallographic and optic axes are imaginary. Paleo-ecology and fossils need to be rebuilt, because they are not around any more. Virtual reality technology is very important tool to enrich the scientific imagination of young geologist. By using the capabilities of the digital game-based learning we can meet the needs of geologic learning styles of today's and future's generations of learners. Digital game-based learning is enormously versatile, adaptable to almost any geologic subject, information, or skill to be learned, and when used correctly, is extremely effective, beside, it is very motivating, because it is fun.

The current study is a product of the Geology Virtual Labs (GVL) development. The goal of this study is to develop and enhance the way of teaching for the Earth Sciences Department undergraduates' basic geologic sciences courses to improve learning and to progress the student teacher interaction to higher levels.

The current research classifies six main earth sciences learning domains that can be visualized through the virtual reality technology. The time domain will help in visualizing and interacting with the past, current and future geologic events. The speed domain will help adjusting the rate of the very low and high speed events to be able for the student to investigate, manipulate and interact. The size domain is concerned with visualizing regional, mega-geologic and micro-geologic features, and provides suitable environment for investigation. The imaginary parameters domain will let the student visualize and interact with these parameters. The hidden domain is representing under ground structures especially those are dealing with groundwater and petroleum exploration.

We did our best to use games to engage the earth sciences student in the earth sciences world, taking in consideration the main structural elements of games: 1- Rules, 2- Goals and Objectives, 3- Outcomes and Feedback, 4- Conflict/ Competition/ Challenge/ Opposition, 5- Interaction, 6- Representation or Story.

The Game-based technology using the virtual reality capability help us see and virtually live and interact in the above mentioned domains that were not possible before without these electronic technologic advancements. This framework is greatly recommended to be considered in teaching earth sciences courses as complementary to the current conventional laboratory.

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