Creating Web-Based Animation in STEM Education

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ABSTRACT

We present educational web-based animations to facilitate teaching and learning in STEM courses. These animations incorporate engaging graphics, sound and user interaction to explain a particular topic. They have been developed by IT junior and senior students who closely worked with faculty of STEM courses such as Chemistry, Mathematics, and Biology who were interested in having animations developed for their courses. These faculty members acted as "clients" by providing a topic to the student developers, who gathered requirements, designed, developed, implemented and tested the animations.

Keywords: e-Learning, STEM, animations, games, web-based learning.

1. INTRODUCTION

Learning style dimension refers to the individual's unique approach to learning based on strengths, weaknesses, and preferences [22]. This area has historically been active on research since it has a direct impact on students' understanding of academic material [1, 2, 12, 14, 15]. Research results have concluded that students learn in many ways, such as seeing and hearing, reflecting and acting, memorizing and visualizing [1, 2, 3, 12]. Teaching methods also vary, and students respond better when an instructor's teaching style matches their learning style [12, 13, 16, 17]. According to [1], the predominant teaching style in college is auditory, or a visual representation of auditory information (words and mathematical symbols written in texts and handouts, on transparencies, or on a chalkboard). Mismatch of learning and teaching style leads to poor student performance as well as frustration inside and outside of the classroom, which eventually results in a loss of potential scholars, many of them in STEM-related fields [3, 5, 6, 7]. On the other hand, the U.S. Department of Labor, Bureau of Labor Statistics projects high growth rates in STEM fields for 2008 through 2018[8]. According to the report, projected growth occupations include biomedical engineers, network systems and data communication analysts, life scientists, medical scientist, biochemists, computer software specialist, and theoretical and applied mathematicians [9]. As STEM-related occupations are essential to remain competitive in the global marketplace and support continuous economic growth, it is critical to produce graduates in STEM-related fields, who are prepared to join the workforce.

In order to recruit and retain students in STEM fields, research results indicate that it is important to provide innovative teaching techniques, which utilize visualization [3, 4, 5, 6, 7]. The traditional visual materials such as pictures, diagrams, sketches, process flow charts and network diagrams are stationary and thus, they are rigid, lack interactivity and are not suitable to show time-based processes. To this respect, computer animations are a valuable educational tool since they combine attractive interactive time-based graphics with sound to create a rich learning experience. These animations have been successfully used by computer science faculty to teach subjects such as data-structures and computer algorithms [6, 18, 19, 20, 21]. In contrast, faculty in non-computer related disciplines lack the skills to create animations, so it is crucial to have collaboration between educators in computer-related fields with those in other areas.

Even though educators have realized the importance of using visualization, interactive visualization tools such as web animations, they have not been widely used to assist with the teaching of STEM courses mainly because of lack of resources. As a result, little research has been conducted to study the actual impact of using interactive visualization tools to meet the needs of different student learning styles [2, 4]. Answers to questions such as "To what extend does using animation tools help engage students?" or "To what extend do they improve student performance?" remain unclear. In this paper, we present a pilot project that demonstrates the collaboration between IT and other disciplines to develop web animations to assist with the teaching and learning in STEM courses. In addition, we also show preliminary research results on the impact of these animations on student's learning outcomes through qualitative and quantitative analysis.

2. PROJECT PLANNING

In this project, we present educational web-based animations to facilitate teaching and learning in STEM courses. These animations incorporate engaging graphics, sound and user interaction to explain a particular topic. They have been developed by IT junior and senior students who closely worked with faculty of STEM courses such as Chemistry, Mathematics, and Biology who were interested in having animations developed for their courses. These faculty members acted as "clients" by providing a topic to the student developers, who gathered requirements, designed, developed, implemented and tested the animations. These animations have the potential to impact not only the faculty clients and their students but also other faculty who teach the same topics. In addition, student developers gained valuable experience on research methodology as well as technical skills in graphics design, web animations and programming.

Once an animation on a particular topic is completed, faculty members can use it to teach that topic in their course. Pre and post quiz survey data are collected to determine the impact of using animations in the teaching/learning stage. These data give insight of how web-animations affect student learning and engagement.

3. IMPLEMENTATION

Recruitment. We recruited four senior IT students to enroll in an interdisciplinary research project to develop web-based animations for STEM courses. These students had previously completed the course "Computer Graphics and Multimedia," where they were exposed to applications used to create web-based animations. Conversely, we employed six STEM faculties in the areas of Chemistry, Mathematics, Biology, and Exercise Science, who provided our students with topics in related areas. These faculties were referred to as "clients".

Development. Student developers began meeting with clients in early September, 2011. The development process was as follows. Developers meet with the client. During the meeting, they gather requirements and come up with a sketch or rough design document. The next step consists in the discussion of ideas with fellow developers and research faculty. Later, they create a prototype animation and ask researchers and clients for feedback, which usually results in minor modifications or error fixes rather than drastic changes. After the prototype is approved, students work on the testing phase, to ensure the delivery of a reliable product. After full completion, the animation is uploaded into the project's website, to make it available to all faculty and students. Development phase ends with the developers' formal presentation of the animation to the client(s).

Data Collection. Once the animation is approved, the client uses it in his/her class. Researchers and clients prepare pre and post surveys to measure the effectiveness of the animation as a teaching and learning tool. The client's students will then proceed to fill out the pre-survey, use the animation and complete the post-survey.

4. RESULTS

The development phase lasted two semesters and produced 10 animations. These animations were presented to faculty clients as well as to the general audience of the Science Technology and Research Show (STaRS), which is sponsored by the School of Science and Technology at Georgia Gwinnett College to promote STEM disciplines.

The finished product consisted of 4 animations in the area of Biology, 3 in Mathematics, 2 in Chemistry, and 1 in Exercise Science. We now provide a brief description by area.

Biology

- The first animation is *Pompe's disease* (Figure 1), which presents an illustration of a muscle cell with glycogen and glucosidase in normal conditions and explains what happens when glucosidase is deficient and lysosomes glycogen are not degraded.

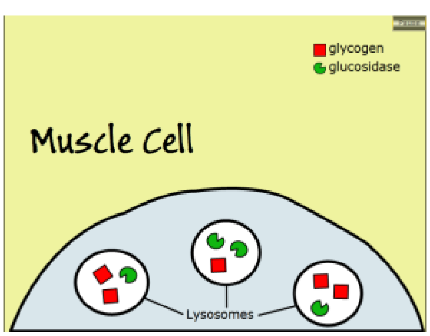

Figure 1: Pompe's disease

- The second animation *The cell and its parts* (Figure 2), shows a diagram of a cell explaining each part one at a time allowing the viewer to pause the animation at any time.

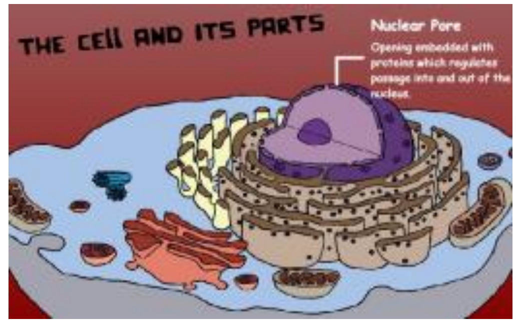

Figure 2. The cell and its parts.

- The last two biology animations explain the physical phenomenon of Nuclear Magnetic Resonance (NMR) (Figure 3).

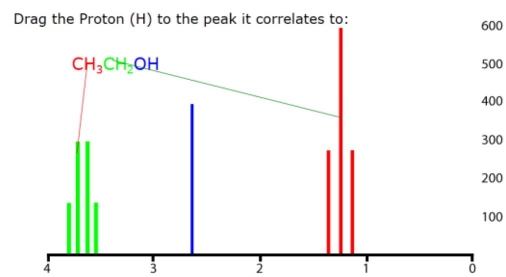

Figure 3. Nuclear Magnetic Resonance (NMR).

Mathematics

- The initial animation is Symmetry of Squares (Figure 4), which displays a square with corners labels 1 through 4. The square can be rotated 90^o, reflected over X and Y axes as well as diagonally. Compound operations involving several rotations and reflections are also supported.

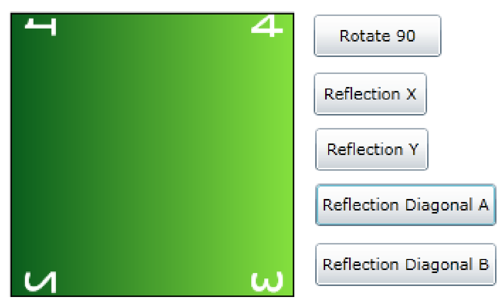

Figure 4. Symmetry of squares.

- The next animation (Figure 5) displays the Cartesian coordinate system with several well-known functions such as $\sqrt{x}$, x^2, x^3, $|x|$, etc. The user can experiment with the graphs by clicking buttons, which allow to visually see the differences among f(x+1), f(x-1), f(x)-1, f(x)+1, etc.

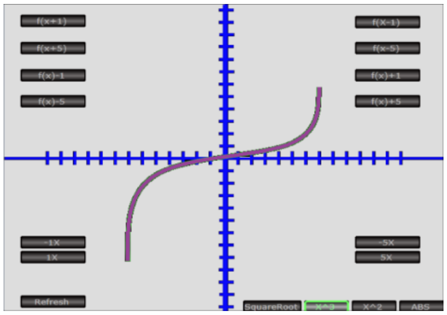

Figure 5. Algebra functions.

- The last animation (Figure 6) illustrates the central limit theorem by allowing students to experiment by rolling several dice and comparing results of multiple experiments.

Figure 6: Central limit theorem

Chemistry

- The first animation is Hydrohalogenation (Figure 7), which illustrates the electrophilic addition of hydrogen chloride.

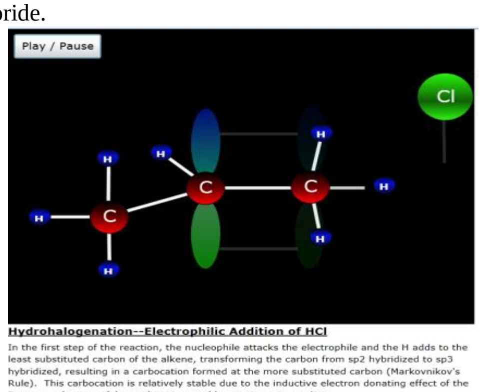

Figure 7: Hydrohalogenation

- The second animation provides an overview of the metric system, how to use it and its differences with the United States customary units (Figure 8).

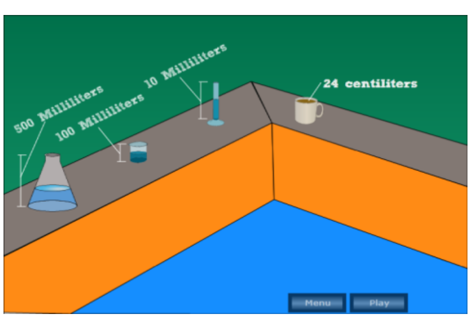

Figure 8. Metric system.

Exercise Science

- An interactive animation for muscle contraction allows students to visualize the differences between ipsilateral, posterior and contralateral movements (Figure 9).

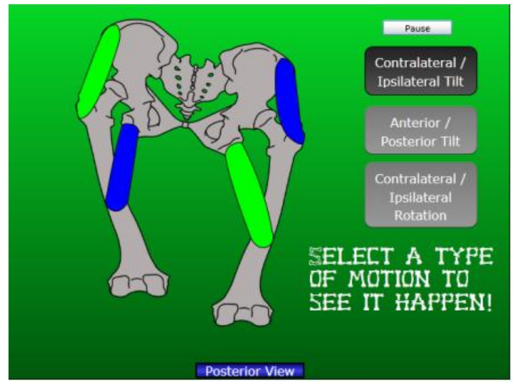

Figure 9: Muscle contraction

5. PROJECT REFLECTION

All faculty clients gave positive feedback about the professional manner in which student developers worked as well as the quality of their final animations. In the final project report, student developers also expressed positive view of the overall development of this project. The animation project allowed students to acquire the following:

- Ability to develop and test the animations.
- Ability to document the IT solutions.
- Ability to utilize the web and other open-source tools to collaborate during IT research.

In addition to the acquisition of IT skills, they stated that this project also promoted their problem solving, and soft skills which include:

a. **Communication**. Students had to setup multiple meetings with each faculty client during the development cycle in order to:

- Discuss the initial animation idea and gather client requirements.
- Demonstrate the animation product, gather feedback and modify the product (repeatedly).
- Deliver the final product to the client.

Students also needed to communicate with faculty supervisors to report the development progress and discuss the challenges they have encountered.

b. **Critical thinking and creativity**. Students needed to interpret the client's idea and convert it into an animation that satisfied the client's needs.

c. **Collaboration**. Students worked in groups for some of the animations. In order to complete the animation, they had to communicate and collaborate with each other. Even though some animations were completed individually, students discussed the technical difficulties with other developers and assisted each other to meet the deadlines.

d. **Time management**. As junior and senior students, developers took multiple number of higher level IT courses, which require significant amount time. Moreover, all of them were also working part time, which made it difficult to find time to work on the project unless appropriate time management skills were utilized. According to our students, time management has become one of the biggest challenges, and this project provided an opportunity for them to improve. They believe such experience was beneficial to their future career.

6. CONCLUSION AND FUTURE WORK

The entire project produced ten animations for STEM courses. The results have shown at presentations on campus, which generated a broad interest from faculty. We plan to continue recruiting students and develop more animations to build a repository of animations for different STEM courses at various levels.

We have also designed pre and post surveys to evaluate the effectiveness of those animations. In the future, we will conduct research:

- To investigate students' learning behavior and preferred learning style in STEM courses.
- To investigate the effect of visualization, particularly web animation, in teaching/learning STEM concepts.

We will also collaborate with faculty "clients" to conduct surveys and interviews in order to discover the effectiveness of the animations.

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