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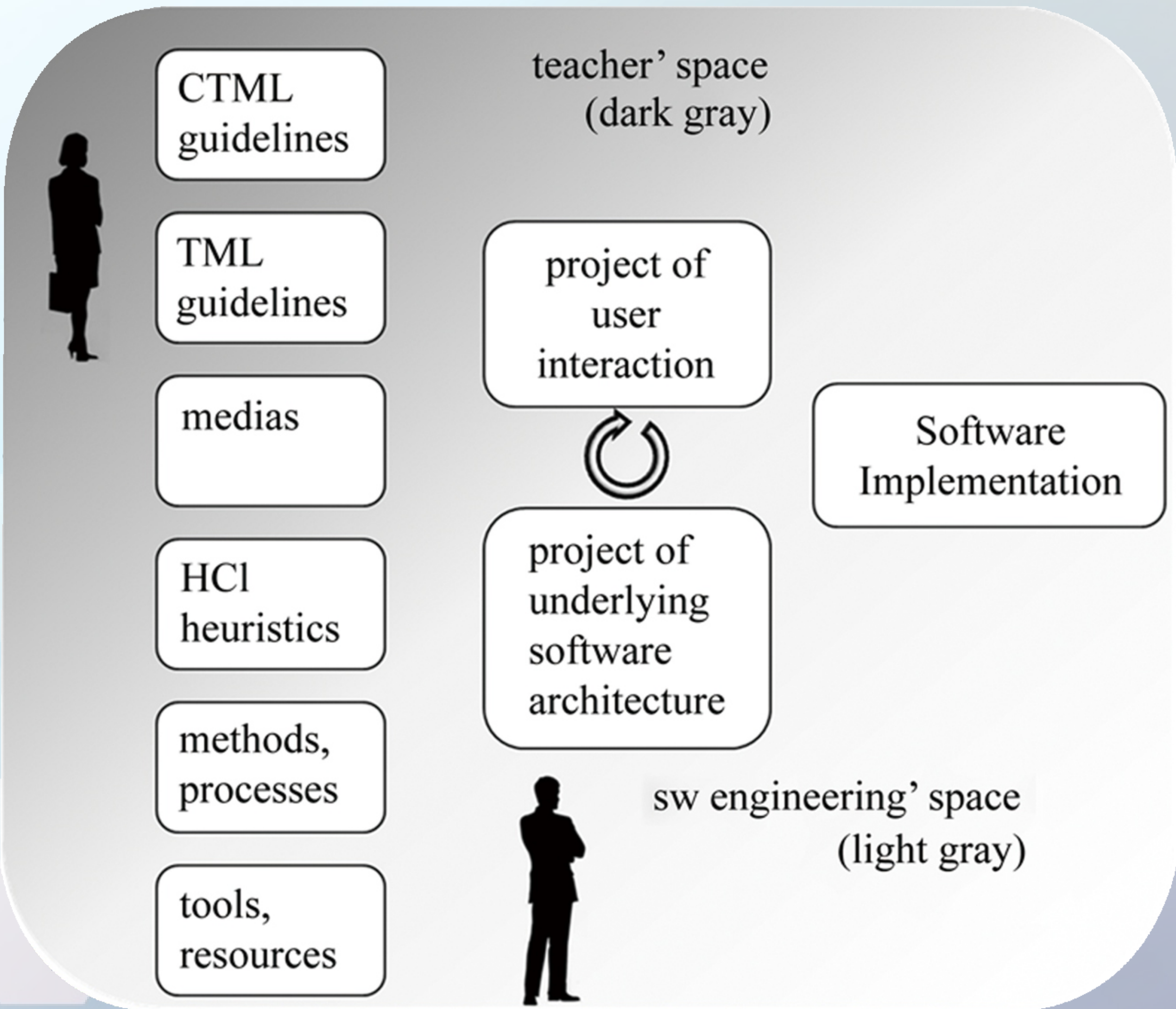

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Sound, Waves and Communication: Students' Achievements and Motivation in Learning a STEM-Oriented Program

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Abstract

In this article, we present the case of developing an interdisciplinary curriculum for learning science and technology, its implementation in junior high schools and evaluation of students' achievements and attitude. The 30-hour course (15 two-hour sessions) includes subjects such as sound and waves, conversion of sound to electrical signal, amplification, sampling, and analog to digital conversion. Beyond teachers' short presentations, the students are engaged in problem solving and project-based learning, with strong emphasis on using information and computer technologies (ICT) tools such as simulation and sound editing software. One could see that the course design was guided by the following principles: contextual learning, integrated learning of science, technology and computer sciences; extensive use of information and computer technologies (ICT); and combining teacher's instruction with project based learning. The research aimed at exploring students' achievements and motivation to learn science, technology and computers. The participants in the pilot study were 40 junior high-school students in 7th grade (age 13). In the near future, the course will be updated and run once again among junior high school students and student teachers in a regional college. Data collection tools include: achievement tests, attitude questionnaires, interviews with teachers and students, and analysis of the students' assignments and projects. The findings indicate that the students manage to handle the subject fairly well and have good achievements in the final exam. The learners also succeeded in developing final projects in sound and communication systems, "The human ear" and "Bluetooth", and presented their projects to the parents.

Keywords

STEM, Interdisciplinary, ICT

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1. Introduction

Educators agree that one of the keys in fostering learning in school is linking subject matter and instructional methodology with students' real-life situations, experiences and interests (Dewey, 1963; Bruner, 1996). Technology offers powerful tools for the realization of these instructional concepts by means of simulating real-life situations or connecting classroom context to the outside world such as the community, business or practitioners in science and technology (Bransford, Brown, & Cocking, 2000).

Today's youth are living in a digital culture, making extensive use of advanced technological devices such as laptops and cell-phones in daily life. These technologies are all based on scientific, technological and mathematical knowledge. However, science and technology instruction in school is still mainly supported by laboratory experiments and the passive transfer of information from teacher to student. A viable and necessary change is that education should be connected directly to the real world outside the school (Roberson, 2011). For science and technology education to be successful, elements of the culture affecting students must be carefully considered and integrated into the curriculum.

Realization of these principles, with a strong emphasis on using information and computer technologies (ICT) tools such as simulation and sound-editing software may allow the establishment of an advanced scientific-technological environment having the potential to combine science, technology, mathematics and engineering, and linking them to the real world outside the school.

The current study presents a research focused on the development, implementation and evaluation of a science, technology, engineering, mathematics (STEM)-oriented curriculum for interdisciplinary learning in science and technology in an online environment. From the perspective of technology education, the students are engaged in constructing and testing technological artifacts, and learn technological concepts such converting sound to electrical signals, amplification, data sampling, analog-to-digital conversion and communication systems. Learning these subjects has to do with understanding central concepts in technology and engineering, for example system thinking and modeling. For example, in the "Concepts and Context in Engineering and Technology" (CCETE) study conducted by Hacker, de Vries, & Rossouw (2010), an international panel of experts identified the following three (out of 10) main concepts for engineering and technology education: 1) design (as a verb); 2) systems; and 3) modeling. Therefore, this case could be a good example of teaching technology under the wide umbrella of STEM or science and technology education.

2. Conceptual Framework for Teaching "Sound, Waves and Communication" Concepts

The conceptual framework for the proposed schooling consists of four main ingredients: contextual learning, interdisciplinary learning, project-based learning and technology-supported learning, as illustrated in **Figure 1** and discussed in the following sections.

2.1. Contextual Learning

The term contextual learning has to do with learning that relates to a learner's diverse life contexts such as at home, during leisure time, social or environmental activities, or in the students, having opportunities to make meaning of their disciplinary knowledge and solve problems within a real world context (Karweit, 1993). For the student to be able to develop the required elements in problem-solving process: procedural fluency, conceptual understanding, strategic competence, adaptive reasoning and productive disposition (Schunn & Silk, 2011), he must be involved in well-designed problems.

2.2. Interdisciplinary Learning

Interdisciplinary learning is about providing students with opportunities and space for learning beyond subject boundaries and making connections between different areas of learning (Rowntree, 1982).

STEM—science, technology, engineering and mathematics

The term STEM (science, technology, engineering and mathematics) has caught the attention of educational research as a framework for fostering science and technological literacy learning in schools. STEM recognizes the importance of science and mathematics, and places special emphasis on technology and engineering as fields that affect our lives, and is especially important to society interested in constant renewal (Bybee, 2010).

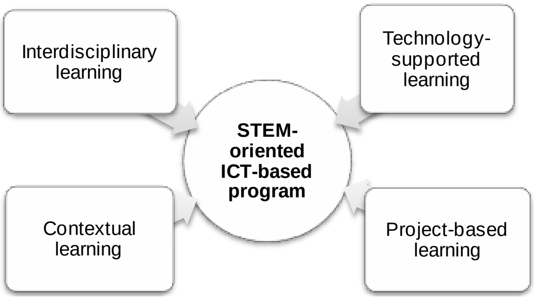

Figure 1. Major principles of the learning environment examined.

Katehi, Pearson and Fidir (2009) argue that technology and engineering should be given their appropriate places in school's programs in order to ensure interest and creativity.

2.3. Project-Based Learning

Educators are increasingly recognizing that project-based learning (PBL) is considered a natural framework for the implementation of constructivist learning, and a good platform for fostering the student's cognitive skills. The application of PBL in science and technology aims at placing the learner in an active role where he investigates or solves a major real life problem that is driven by a research question and consists of a number of tasks (Savery, 2006; Barak & Shachar, 2008).

2.4. Technology-Supported Learning

Technology can help in the scientific learning process because of its potential to support activities such as data collection, visualization, meaningful thinking, problem solving and reflection. Special emphasis was placed on using simulation and animation, which has emerged as one of the most popular instructional tools for delivering quality instruction. The use of realistic simulation often requires students to apply newly acquired skills while motivating them toward advanced learning (Hsu & Thomas, 2002; Lewis, Stern, & Linn, 1993; Moreno & Mayer, 2007; Weller, 2004).

3. The Sound Waves and Communication Systems Course

The course is designed for junior high school students and consists of three phases as described in **Figure 2**.

Following are examples of material taken from the basic level: **Figure 3** is an animation showing that sound is cyclical fluctuations of particles; **Figure 4** shows a chart of a sound system; **Figure 5** describes the major phases of the analog-to-digital conversion process; and **Figure 6** illustrates a simulation carried out for sampling a signal where students can control the sampling frequency and watch the signal obtained.

3.1. Instruction Method

1) *Teacher's presentation and demonstrations*

At the beginning of each lesson, the teacher presented basic principles of theoretical material to the students for 20 - 30 minutes using rich presentations with animations. Moreover, he introduced his students to different electronic systems such as radio and bell entrance (**Figure 7(a)**).

2) *Student's experimentation by simulations and interface with the computers*

Following the teacher's short presentation, the students were engaged in problem-solving tasks, with strong emphasis on using information and computer technologies (ICT) tools such as simulation and sound-editing software. At the end of the lesson, the students sent their answers to the teacher. Aside from the computer activities, the students learned scientific concepts in experiential ways. For example, in order to learn the frequency concept, the students produced different voices trying to demonstrate a high tone and a low tone. They played musical instruments such as a flute, drum and xylophone, and entered websites, connected headphones, controlled the frequency of the signal and heard how the sound changed (**Figure 7(b)**).

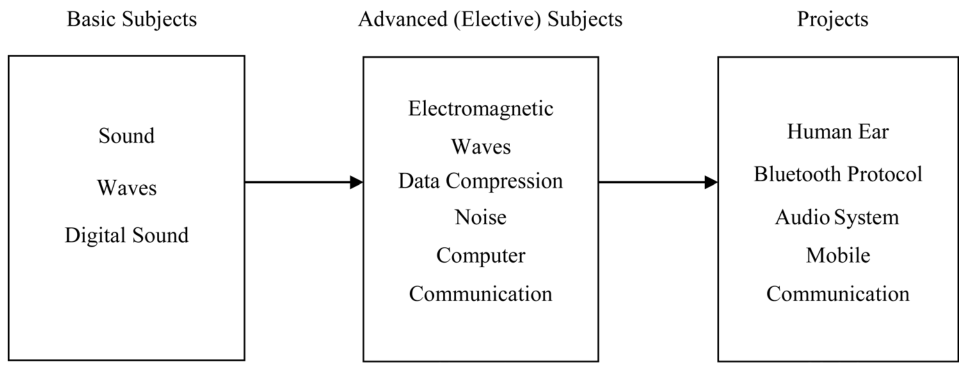

Figure 2. The course design.

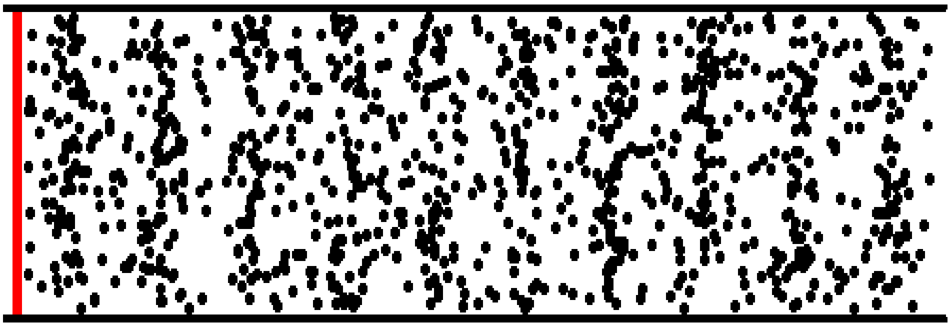

Figure 3. Sound as a movement of particles.

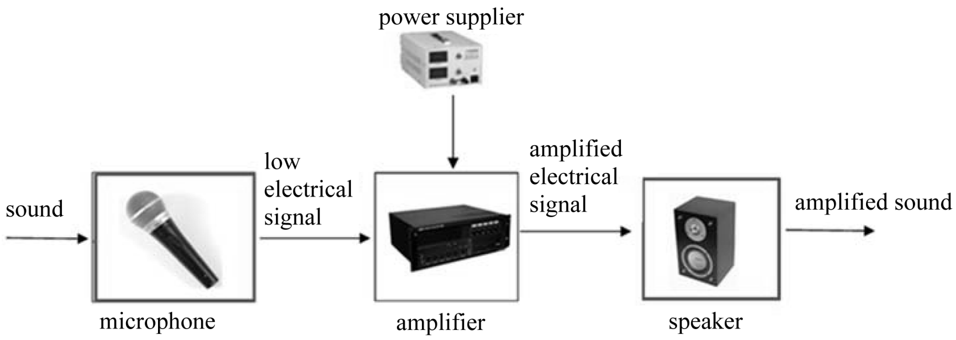

Figure 4. Sound amplification system.

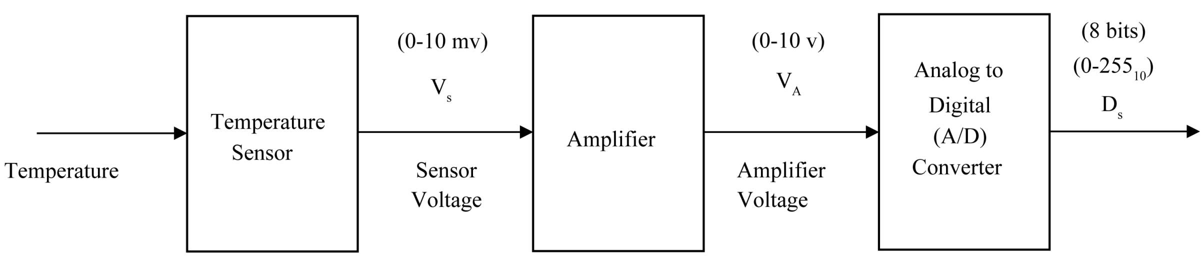

Figure 5. Sampling and analog-to-digital conversion process.

3) *Artifacts construction*

Some lessons were devoted to experiential learning during which students were engaged in creating accessible products. For example, students of one group built a model of a simple speaker from basic components. A second group built a simple radio using an electronics kit (**Figure 7(c)**).

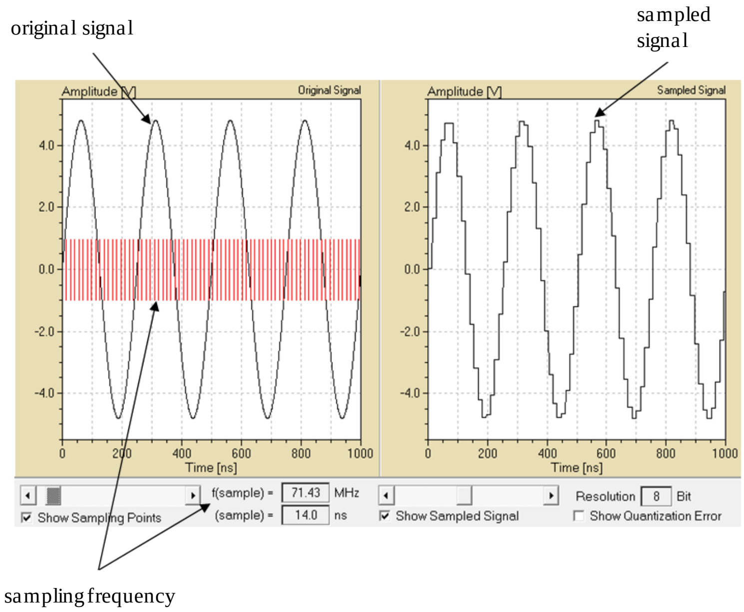

Figure 6. Simulation of sampling a sound signal.

(a)

(b)

(c)

Figure 7. Examples of classroom activities for students. (a) Examining an electronic system; (b) Listening to sounds on a computer; (c) Building a speaker.

3.2. Project

In the second part of the course, the students were engaged in project-based learning on topics that interested them, such as “digital music”, “mobile communications”, and “the human ear and hearing”. Students were guided in searching information and data from various sources to understand their subject matter in depth. Their task was to prepare 8 - 10 pages including the following chapters: introduction, body—a description of three to four main points, results and conclusions, sources, and personal reflection. At the end of the course, the students presented their projects to their class and during parents' day.

4. The Research

4.1. Research Questions

The current research, which aimed at exploring students' achievements and motivation to learn science, technology and computers, was guided by the following questions:

To what extent can junior high school students learn an advanced scientific-technological subject such as sound, waves and communication systems? What factors contribute to or hinder their success in learning the subject? What is the impact of studying the subject on students' in relation to:

a) Motivation and interest in learning science and technology.
b) Self-efficacy perception of studying scientific-technological subjects.
c) Desire to learn in an online environment.

4.2. Participants and Setting

The study took place in a regional enrichment educational center, and the students came from four different cities in northern Israel. The participants comprised two separate groups of 20 students each (7th grade, age 13 - 14) for a total of 40. Each group studied for two periods a week over 15 weeks.

4.3. Data Collection

The study adopted a mixed method, combining quantitative and qualitative methods, aimed at shedding light on as many aspects as possible of students' activities in the class, their achievements and their attitudes toward the course. The quantitative tools included a closed-ended attitude questionnaire and an achievement exam; the qualitative tools were an open-ended questionnaire, observations, interviews and analysis of the students' work. More specifically, the data collection included:

- Documenting students' activities in the class. The researcher attended the course and documented comments about the students' motivation and success in performing the class activities, the students' statements and special events.
- Analyzing the outcomes of a 90-minute exam that students answered at the end of the course.
- Administering a semi-structured attitude questionnaire distributed to all students before and after the course.
- Conducting 10 interviews with groups of 2 - 3 students at the end of the lessons.
- Interviewing six parents on parents' day at the end of the course.
- Analyzing class activities and final projects that the students had submitted.

5. Findings

5.1. Students' Achievements in Learning Scientific-Technological Subjects

We used a 1 - 1.5 hour exam to assess the knowledge acquired by the students. The final version of the exam was validated by science and technology teachers having extensive experience who are studying for an MA degree in science and technology education at Ben-Gurion University of the Negev.

The exam consisted of one question about declarative knowledge, two questions about procedural knowledge and two questions about conceptual knowledge. Below are examples of exam questions about each knowledge type:

- Regarding declarative knowledge, the students were asked about facts such as the speed of sound in air, human hearing range, etc.
- Regarding procedural knowledge, the students were required, for example, to calculate the velocity of the wave (using the formula $v = \lambda * f$).
- **Figure 8** shows an exam question of conceptual knowledge where VA represents the input signal to the amplifier while VB represents the output signal. The students were asked to identify the amplifier's amplification, draw a graph that describes the relationship between VA and VB, and calculate the overall amplification of two amplifiers connected in series.

The teacher and the researcher checked four exams together and concluded how to evaluate the rest. After

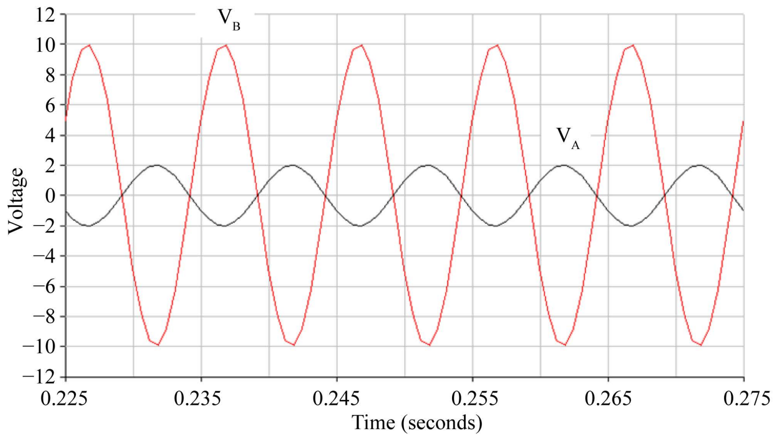

Figure 8. An exam question requiring conceptual knowledge.

checking the exams separately, they decided each student's score together. The average total score (on a scale of 0 - 100) was 82 (n = 36, SD = 12.7). The highest score was 100 and the lowest was 60. More specifically, the average score for the declarative knowledge questions was 80 (SD = 22.17), for the procedural knowledge questions 85 (SD = 36.2) and for the conceptual knowledge questions 80 (SD = 29.18). These outcomes reflect the fact that science and technology teachers often emphasize learning procedural knowledge. The findings show that students were more capable of dealing with questions based on procedural knowledge such as calculating physical quantities using formulas. Moreover, the good achievements of the students regarding questions based on conceptual knowledge show that they acquired significant knowledge on scientific-technological topics studied in the course.

5.2. Findings from the Students' Questionnaires

One objective of the sound, waves and communication systems course was to bring students closer to the world of science and technology, and foster their interest in this field. To explore students' viewpoints in this regard, a structured questionnaire was administrated in the classes before and after the course. The questionnaire included 12 items spread over three categories:

1) Motivation and interest in learning science and technology. For example, I am interested in studying science subjects.

2) Desire to learn in an online environment. For example, I look for information on the Internet in my free time.

3) Self-efficacy beliefs about learning new topics. For example, I can study alone and learn more about science.

The students marked their answers on a Likert scale (1 = very low; 2 = low; 3 = high; 4 = very high). Half of the items in the questionnaire appeared in a negative form, for example, "It is difficult to learn new scientific subjects alone," to avoid bias in the outcomes because of individuals' tendencies to answer questions positively. Answers to "negative" items were converted into a positive scale in the data analysis. The questionnaire also included an open-ended section: several empty lines were left next to each item in which the students were asked to explain or give examples of their answers in their own words. Most of the students wrote relevant things, and the researchers learned additional valuable information about the students' viewpoints in the questions discussed. In addition, the students' authentic answers indicated whether they had answered the closed-ended questions carefully. Twenty-nine students answered the questionnaire before the course, and 31 students answered it after the course.

To check the reliability of the questionnaire findings in terms of internal consistency, Cronbach's alpha test was performed. The results were 0.67 for motivation and interest in learning science and technology, 0.53 for the desire to learn in an online environment, and 0.58 for self-efficacy beliefs about learning new topics. The findings of the three categories of the questionnaire before and after the course are presented in **Figure 9**.

The average score of students' answers to the questionnaire after the course was slightly higher than that before the course in all three categories, although these differences are not statistically significant. A possible

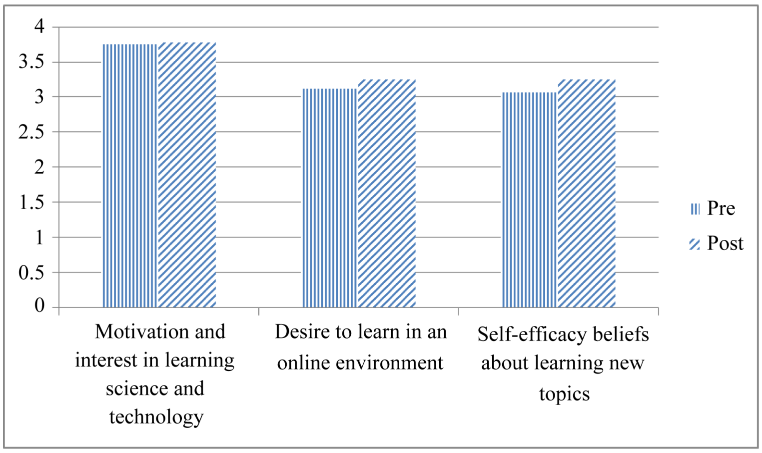

Figure 9. Average scores of students' answers to the attitude questionnaire. Scale: 1 = very low; 2 = low; 3 = high; 4 = very high.

explanation for these results is that the students were interested and motivated to learn new subjects before they learned the course under discussion.

5.3. Findings from the Students' Final Projects

As previously mentioned, project-based learning may contribute to fostering learning skills among students. However, the implementation of this method in school is not easy and requires considerable effort from both the teachers and the students (Barak & Shachar, 2008). In this study, the students prepared projects on subjects in the field of sound, waves and communication systems during the final four weeks of the course. The students worked in pairs and chose topics that interested them as shown in **Figure 10**.

For their projects, the students were required to prepare a presentation or a website of 8 - 10 pages including the following chapters: introduction, body, results and conclusions, sources, and personal reflection. The students received an explanation and a detailed document about the structure and scope of each chapter from their teacher.

Figure 11 presents partial content of projects developed by two students on "Bluetooth communications". The students explained how two devices using Bluetooth can create a network that prevents the penetration of other devices into the network by randomly changing the frequency 1600 times.

In the students' reflections regarding the project development process, many expressed their satisfaction and interest in learning new subjects. Some noted difficulties they had encountered and methods of overcoming them.

Using technology as tool for learning

As the students worked on their projects, they invested serious efforts in seeking new sources, making an appropriate use of keywords in the search for and utilization of web-based information. They downloaded digital books on issues relevant to their subject matter and used diverse computer software (such as MS Paint, Word, PowerPoint, Screen Capture and Audacity) to prepare and present their projects. Five students managed to learn Google sites platform by themselves and presented their project through a website that they developed.

5.4. Findings from Observations in the Class and Interviews with Students and Parents

The researcher attended nearly all of the class lessons in both study groups and prepared a detailed diary of special events, activities and responses of the students. Ten interviews with groups of 2 - 3 students were carried out after class lessons throughout the course. The interviews were recorded, transcribed and analyzed. Because of the limited scope of this article, we present below only a few examples from these findings.

The researcher asked the students questions such as: "What is the difference between learning in the course and learning in school in general?" Students answered:

"It is different from the school class... There we learn only theoretical things throughout most of the year."

"Here we learn about practical communication… In school, we only learn words."

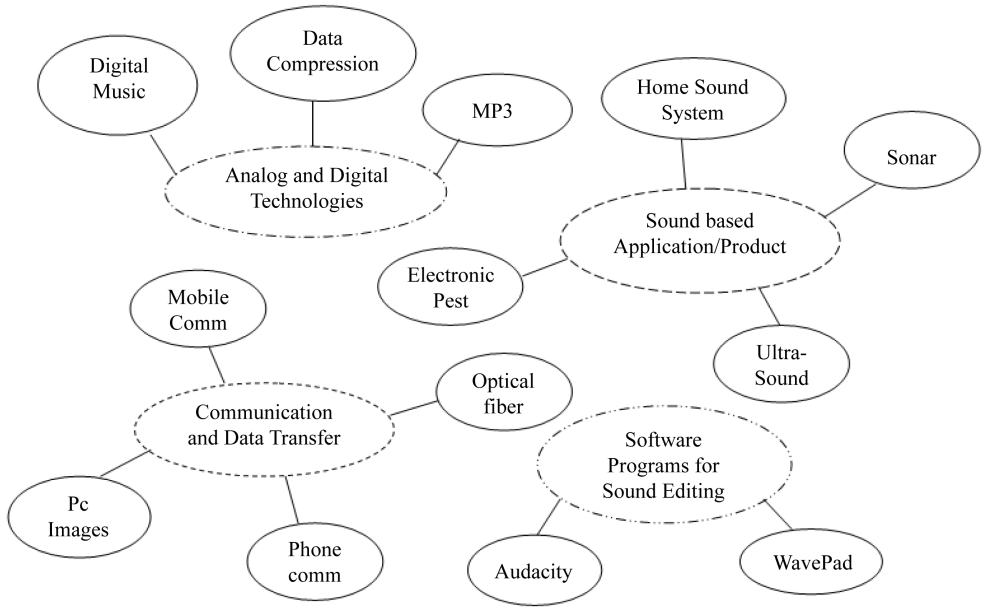

Figure 10. Examples of projects that students chose.

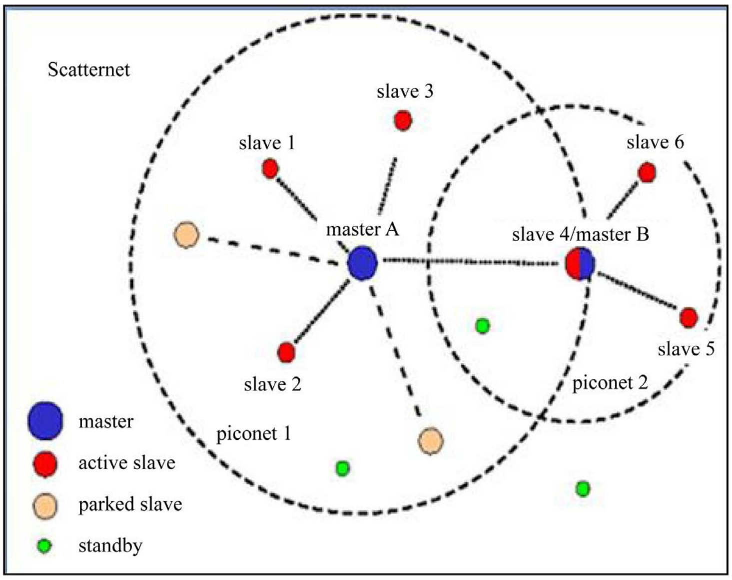

Figure 11. A slide from a project about Bluetooth communications.

Other students declared that working on a real product helped them understand the major role that theoretical subjects play in practical reality. For instance:

"To make the speaker work, we tried magnets of different sizes with various coils of the copper wires."

"The beauty is that I can see immediately if things work or not."

6. Conclusion

The findings of this study indicate that students at this age can deal successfully with learning a relatively complex and interdisciplinary subject that spreads over a number of areas in science and technology. According to the students' perspective, it is not essential to define whether a subject belongs to physics, electronics, computer science or mathematics. The main factors that contributed to learning were the combination of the teacher's explanations (traditional teaching), students' learning in a rich technological environment, and the projects they prepared. Choosing topics related to the students' world such as sound amplification systems and digital sound was a key factor in creating motivation in learning the theory and preparing the final projects. Using computers and ICT technologies, not only for teaching the subject but also for documenting the learning process and presenting the project to class members and parents, contributed greatly to students' motivation throughout the course.

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Increasing Learning Motivation and Student Engagement through the Technology-Supported Learning Environment

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Abstract

Education is one of the most important elements in our lives because it is a direct way to broaden our knowledge. In order to enhance academic learning experience, an increasing number of instructors are changing their pedagogies to make their students socially active in class participation. In this article, the author describes how the development and implementation of the technology-supported learning environment will be beneficial in student and instructor engagement and the overall learning motivation. The author first provides detailed implementation of the technology-supported learning environment. Next, she explains how to utilize such environment to increase in-class participation and to support collaborative learning. She then examines students' overall learning and feedback, and analyzes the costs and benefits of this pedagogy. Finally, she concludes that this environment can promote greater classroom engagement and support collaborative learning.

Keywords

Instructional Design, Group Activities, Collaborative Learning, Surveys/Feedbacks, Technology

1. Introduction

Teaching is the fundamental mission of any university or college. The creation of new knowledge is of little value without the ability to pass on that new knowledge, and existing knowledge, to the next generation. It is important to understand how students learn and to know when they might confront difficulties with new concept. For past decades, traditional lecturing has used an instructor-oriented approach, where the majority of the class time depends on the instructor's delivery of knowledge. The drawback of such lecturing is that there is little interaction between instructors and students, as students tend to engage only passively with the material. Several

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scholars believe that instructors focus too much on teaching content and not on engaging students on traditional lecturing. As a result, it is hard to find out the difficulties that students might encounter, and thus, students must be actively engaged in the learning process in order to have a meaningful and long-lasting learning experience (Barkley et al., 2014; Pascarella et al., 2005; Edgerton, 1997; Shulman, 2002).

Interactive lecturing, on the other hand, includes short activities that allow students to recall and enhance their knowledge. The benefits of interactive lecturing include greater in-class engagement and collaborative learning. Collaborative learning, by definition, means that students achieve their learning goals via a group-based approach (Dillenbourg et al., 1995). Some benefits of collaborative learning include enhancing learning satisfaction, promoting positive attitudes toward subject matter, improving students' teamwork skills, encouraging more in-class participation, promoting greater in-class attention, creating more in-class interaction, and developing higher-order thinking (Srinivas, 2014).

Since technology has become integrated into in our daily life, interactive lecturing with technology has become a groundbreaking advancement in education. According to Kuh et al. (2001), technology has been proven to improve learning outcomes and engagement. Some scholars (Meyers et al., 1993) believe that higher-order thinking, which facilitates students' knowledge development, is an important concept in education and can ultimately achieve collaborative learning. Thus, it is important to utilize these learning technologies, such as CSCL (computer-supported collaborative learning), to support group collaboration and achieve collaborative learning (Stahl et al., 2006). As a result, I decide to utilize learning technologies so that I can transition my pedagogy from an instructor-centered passive learning environment to a student-centered active learning environment.

The main purpose of this paper is to introduce a technology-supported environment to promote in-class participation and achieve collaborative learning. My contribution includes: 1) discussing the reasons that have made me to make this change; 2) explaining how I implement this technology-supported learning environment; 3) introducing how I utilize these technologies to encourage greater in-class participation and collaborative learning; and 4) analyzing and discussing the effectiveness of this pedagogy.

2. The Necessity of Promoting In-Class Participation and Achieving Collaborative Learning

One of my initial obstacles in becoming an instructor was that I did not know how to encourage student participation. It was a huge challenge for me especially when I was teaching Asian students since they were trained to remain silent in class and follow exactly what instructors tell them to do. That can cause a trend in student learning behavior that is skewed toward self-consciousness. For example, most of the students in Taiwan do not like to speak up in front of the whole class because they are unsure about themselves and feel very uncomfortable to present themselves in public.

Luckily, I was fortunate to join the SST (School of Scientific Thought) program in 2012, in which I attended four useful training session and learned how to actively engage the class participation. In the first session, the coordinators shared some of the experiences from previous years. The coordinators shared us some issues they had encountered in the past and how they solved those problems. In the second session, they taught us how to create our teaching materials appropriately to better suit the students' prior knowledge, as well as how to manage our time for the lectures and in-class activities. They also suggested some ways for us to utilize in-class activities to engage more student participation. During the lunch break, the SST coordinators invited some past SST instructors to talk about their teaching experience. In the third session, I had to pair up with one of the SST instructors and conduct an in-class activity in front of the class. This SST exercise trained me to help me to see how students learn better through class participation. In the last session, each instructor had to simulate a real classroom setting by giving a 60-minute presentation and obtaining comments from other SST instructors after the presentation. Honestly, encouraging student participation was one of my weaknesses before these SST training sessions, and I indeed sharpen my teaching skills from attending these sessions. I was intrigued by these SST training session and had begun to think about how I can increase student engagement in my class. In other words, I believe that by making this change, I can engage both myself and my students with my teaching materials, and can encourage overall classroom engagement.

3. Collaborative Learning

Collaborative learning is one of the important factors that every instructor should emphasize as they develop their teaching pedagogy. By definition, collaborative learning defines as to have students to work together in a small group and to achieve learning goals together. Collaborative learning is a shift from traditional instructor-oriented lecturing to interactive student-oriented lecturing (Kirschner, 2001), and it improves test results and promotes students' interest and motivation in learning (Caldwell, 2007; Pollock, 2006; Sharan, 1980). In addition, Hake (2001) and Gabbert et al. (1986) note that group discussions help students learn better, understand subject matter more quickly, and become more engaged in the class.

Most scholars believe that social interaction a key component in collaborative learning, and there is a large benefit to applying collaborative learning. Some scholars believe that students can develop cognition through social interaction (Vygotsky, 1980; Pascarella et al., 2005; Edgerton, 1997; Shulman, 2002) and can retain information longer through social interaction (Sills et al., 1991). Other scholars consider that collaborative learning strengthens critical thinking and deep learning, as critical thinking encourages students' judgment and problem-solving skills (Gokhale, 1995; McLoughlin et al., 2000; Newman et al., 1995). Moreover, some people believe that the overall learning performance is related to students' interaction with their peers (Barron, 2003; Bruffee, 1999).

Therefore, I have established my teaching pedagogy to support collaborative learning and promote greater engagement. My teaching pedagogy includes incorporating technology-supported environment, constructing in-class activities to encourage in-class participation, and dynamically adjust teaching methods based on their feedback and reactions. I hope that in this way it would stimulate students' learning motivation and ultimately achieve learning goals together.

4. Experimental Setting

My experimental course is called "iTrust: Centralized, Distributed, and Mobile Search", and there are 22 high-school students in the class. In this course, students need to understand the differences between centralized and distributed search engine, identify their trade-offs, explore the iTrust gadgets (desktop, cell phones, and tablets), understand simple statistical equations behind iTrust, learn how iTrust detect/defend some possible attacks over the network, and finally learn how we retrieve and rank the information. The goal of this course is to teach these high school students in the area of science and engineering at a college level, and the topics ranged from nano-technology to real life situations. In my course, I taught my students the following topics:

Week 1: Concept of a distributed search engine and its comparison to existing centralized search engines.

Week 2: Trade-off between distributed and centralized search engines.

Week 3: Construction of a distributed search engine in SMS and HTTP.

Week 4: Calculating the probability of matching keywords in a query and metadata for a document.

Week 5: Detection of malicious attacks in our distributed search network.

In order to adapt the technology-supported learning environment, I perform my teaching practice in a lab classroom, whereas every students gets to have his/her own computer to perform some in-class activities. In addition, my students also have chances to access the iTrust gadgets (tablets and smart phones). I always introduce the class materials during the first hour, followed by in-class activities for students to discuss the lecture materials. After in-class activities are over, students will share their solutions to the entire class, and I will then elaborate some discussions.

5. Student Learning Goals

There are three main learning goals to support collaborative learning and promote greater engagement:

1) *Utilizing technology-supported environment*. Based on recent advance in internet access and mobile phones, many technology-enabled learning environments are being introduced. According to Fisher (2010), he believes that traditional lecturing environment is like a closed classroom that represents a physically outdated teaching model. Fisher collects more than 85% of the positive feedback about utilizing technology-enabled active learning classrooms. The interviewees also believe that technology-enabled learning active environment improves the overall learning outcomes, such as greater engagement, attitude and collaboration. Thus, I believe that having students to learn in a technology-enabled classroom will definitely increase both learning motivations and learning outcomes.

2) *Encouraging fully in-class participation*. In general, class participation allows students to enhance their learning opportunities. Thus, students can get motivated and collaborated with others to learn things together

when they fully participate in the class. However, having students to actively participated in the class was a huge challenge especially when I teach Asian students, since they were trained to remain silent in class and follow exactly what instructors tell them to do. That can cause a trend in student learning behavior that is skewed toward self-consciousness. By trial and error, I figured out that the best way to encourage in-class participation is to assign some in-class activities during my lecture and ask my students to form small groups and work on problems together. Since in-class activities is a form of engaged learning, it allows my students to take classroom leadership in a ways that are not possible in traditional lecture-style classroom, and thus would inspire more learning motivation (Hertel et al., 2002).

3) *Adjusting lecture contents based on students' feedback*. Students would learn best if I adjust my teaching methods dynamically based on their feedback and reactions. From my past experiments, continuous feedback and assessment throughout the class are needed in order to adjust my lecture contents more promptly. For example, if I realized that the level of difficulty was too high for my students, I modified those problems accordingly. Moreover, at the end of my class, I asked my students to complete an evaluation for both the class contents and myself. By doing so, I had a better idea of how they responded to the materials and, consequently, I altered my teaching materials for the following week. In addition, I can determine whether the pace of my lecture and adjust the pace promptly.

In summary, having technology-enabled learning environment, actively engaging in-class participations, and acquiring continuous feedbacks are very critical processes to encourage learning motivation and to obtain collaborative learning. Since teaching and learning is a mutual process, not only do students learn from me, but they also provide me with feedback on my overall teaching performance. By providing the above-mentioned processes, students would increase their interests, and thereby encouraging in-class participation. Once my students are not afraid of actively participate in my class, they would definitely provide comments and feedback. The more feedback I obtain, the better I can understand how students learn and think, and can adaptively adjust my teaching methods accordingly. By doing so, students will be highly get motivated to learn and, be able to apply the concepts to the real world.

6. Analysis and Discussions

I was fortunate to gather feedback from teaching in the SST course at the end of each course. For each week, I generated a set of questions related to class material during that particular week and students had to complete the questions before they left the class. I will evaluate the class activities, class load, level of difficulty, and overall class ratings for the following subsections.

6.1. Evaluation of Class Activities

1) <u>Positive feedback</u>

- "Yes, very helpful and fun too."
- "Today's activities are helpful to understand because we get to learn the materials."
- "Yes, I think they are helpful and I can't wait to use it at home."
- "Yes, very helpful because will help in future."
- "Today was very interesting and informative, thank you!"
- "Yes they are helpful because they help us improve our knowledge."
- "Today's activities were helpful because speaking in front of everybody motivates me to work."
- "I think the class activity do help me learn. I like how you tell us about it and then we work on it."
- "Yes because it is a good practice."
- "I believe it was helpful because it taught me to work in group and make it easier."
- "Yes, I learned to work with a partner and he helped me."
- "Yes the class activity is helpful. It allows me to work with others to solve a problem."

2) <u>Constructive feedback</u>

- "I think today's activity was confusing."
- "Today's activity was difficult."

3) <u>Evaluation of the chart and feedback</u>

We first evaluate the helpfulness of in-class activities. **Figure 1** shows the results of helpfulness of in-class activities categorized by weeks. Based on my past teaching experiences, I believe that students can learn better if

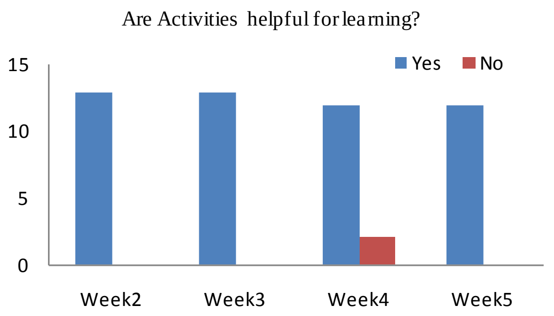

Figure 1. Helpfulness of in-class activities.

they participate more in the class, and thus, I decided to ask the students to provide feedback about these in-class activities. In this way, I was able to adjust the in-class activities for the following lectures.

Most students believed the in-class activities were very useful for learning experience. Based on these positive comments provided above, I believe most students believe the in-class activities were helpful and they could easily learn the class materials. They also stated that they had fun with these in-class activities and found them to be interesting. Some students mentioned that these in-class activities also taught them to work in groups and get to know each other better.

However, there were two students who did not really think the class activities were useful in the fourth week. This is because in the fourth week, I had introduced the students to the C++ programming language, which is a completely new subject for most of them. From these comments, I learned that I should slow down my teaching speed, especially when I introduce new material to the students, so that the students wouldn't get lost so easily.

6.2. Evaluation of Class Load

1) Positive feedback

- "The class materials are just about right. You are very helpful."
- "I think the flow of materials is just about right."
- "It's perfect the amount of materials we get."
- "It is very interesting so it's fun to learn."
- "The materials are challenging enough to learn."

2) Constructive feedback

- "Provide more examples."
- "A little bit too much material. I am just slow at learning."
- "A little bit confusing at one time, but I started to comprehend at the end."
- "Sort of too much. I can understand something but not everything."
- "I think you flooded me with too much materials."
- "Explain more of what the computer is doing in response to our commands."
- "This is too much. I don't want to learn more in depth."

3) Evaluation of the chart and feedback

Figure 2 shows the results for the class load. I was curious to know whether I had introduced too much material in the class, so that I could adjust the in-class load for future classes.

As shown in the **Figure 2**, most of the students believe the class loads were about right (the bar shown in red). From these positive comments, I concluded that most of the students believed that the flow was reasonable and the concepts introduced in my class were very interesting.

However some of the students believed that I still introduced too much material. The reason is that some students believed that I should have provided more examples right after I introduced the syntax of the C++ programming language, so they wouldn't get lost when they started their in-class activities. Others were slow learners and learned only some of the material, but not everything. One student seemed scared at the beginning and was not receptive about learning programming since this was his first time. In response to these comments, I believe that I definitely need to provide more examples during the lectures and to make sure the students understand the material before I move on to the in-class activities.

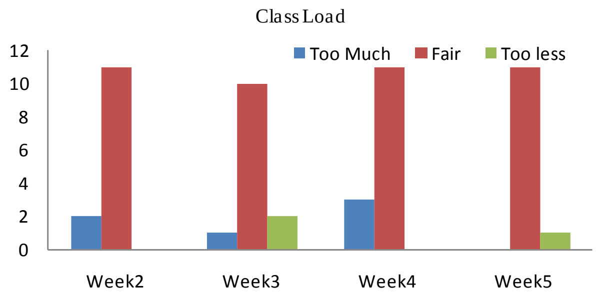

Figure 2. Evaluation of class load.

In addition, **Figure 2** shows how I constantly adjusted my next class topics, based on the students' feedback in the previous weeks. For example, all of the students believed that the amount of contents given in class was a little bit too much in the second week, so I tried to change my lecture slides for the third week. In the third week, some of the students believed the class load was a little bit less, so I appropriately adjusted my class materials. Again, some students felt the course load was a little bit too much in the fourth week. I adjusted it one more time for the fifth week and everyone was satisfied. The most challenging part is to estimate the time it takes for the students to learn. I know that the only solution for this issue is to gain more teaching experience and more feedback from the students by having evaluation forms handy.

6.3. Evaluation of Level of Difficulty

1) Positive feedback

- "It's easy to comprehend."
- "The material is challenging and I learned a lot."
- "Today the material was generally easy to understand."
- "The flow of class is good, and materials is about right."

2) Constructive feedback

- "I am somewhat understanding it, not understanding everything."
- "A little bit too hard."
- "Just a little bit too hard, because it was a little fast."
- "A little too hard but I can manage."
- "I am still confused and don't know what to do."
- "It's just too hard."

3) Evaluation of the chart and feedback

Figure 3 shows the results for level of difficulty of the class. Most of the students believed the materials were about right throughout for all of the weeks. Some of the positive comments indicate that my students believed the amount of class materials introduced was about right.

However, some of the students thought the class materials were still difficult, as indicated by the above constructive comments. As these comments indicated, some of the students understood the concepts partially because it was somewhat too hard for them. Some students pointed out that I introduced the new ideas too fast for them and didn't give them enough time to comprehend. Most of these comments were from the fourth week, when I began to teach them how to write a C++ program. In the fifth week, I gave them a longer review of what we had done at a slower pace. In addition, I gave them another in-class activity which was similar to that in the fourth week so that they could have a second opportunity to learn what was presented in the previous week. Thus, in the fifth week, most of the students believed the class materials were not that difficult compared to the fourth week. Reinforcing the same concept by adding another in-class activity definitely helped them to pick up the material easier. I do think that activities that relate to a certain concept can improve students' learning experience.

In addition, **Figure 3** shows that I am adjusting the level of difficulty based on students' feedback. I lowered the difficulty of my lectures when students reflected to me that the new introduced information was too hard. Similarly, I added more challenging material in the next class when they felt the material was too simple. I believe that it is very important for me to pay close attention to the students' feedback, in order to help students to learn successfully.

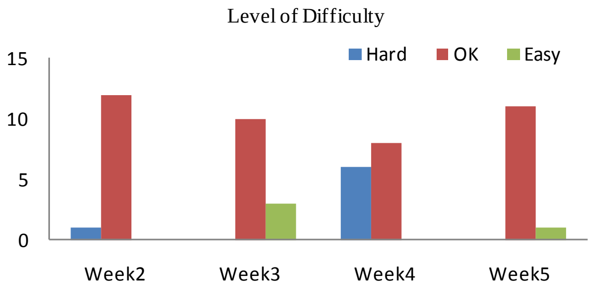

Figure 3. Evaluation for the level of difficulty.

6.4. Evaluation System for Courses and Instruction (ESCI) Ratings for the Overall Class

1) Positive feedback

a) "I like every single field. It was interesting."

b) "I like all the fields introduced in class. They were interesting to learn."

2) Constructive feedback

a) "I don't like writing because I am not very interested in English writing-type activities."

b) "I didn't like the statistics because it was boring."

c) "I didn't like English because I am more like a math person. I want to study something related to math because I like math."

d) "I didn't like computer networks because it was more confusing for me and wasn't much interesting."

3) Evaluation of the chart and feedback

Figure 4 represents the Evaluation System for Courses and Instruction (ESCI) ratings for the overall course. Only 12 out of the 22 high school students responded to the teaching evaluations and, therefore, the results might not reflect the overall perception of students enrolled in the class.

From **Figure 4**, we see that most of the students believe the class handouts were well-prepared and organized, that the level of reading is fair and easy, and the level of math is fair and easy. Because the goal of the SST Program is to inspire high school students to become more interested in Science and Engineering, I tried to avoid introducing very complicated or difficult Mathematics. Moreover, instead of assigning some heavy research papers for them to read, I only assigned newspaper articles or text from the Web for them to read. Most of the students told me that they enjoyed the in-class activities and had a great time in learning programming languages in my class.

In addition, this course was the first time that I actively utilized more in-class participation. From the SST training sessions, I learned that class participation was the key that will lead to students' learning success. As a result, I encouraged my students to become more involved in the class. The students' positive feedback further confirmed that these in-class activities were beneficial for learning the class material. Most of the students thought the topics were exciting and believed that it would be beneficial for their future careers. Lastly, some students were eager to learn more by extending the duration of the program.

In one of my sessions, I asked the students to read some newspaper articles, write a brief summary, and present to the class what they had read. Some of them did not like this part and mentioned that I could perhaps omit this activity in the future. However, in the future I would still assign similar writing and reading activities to my students since it is essential to learn how to analyze articles and practice writing skills. I was influenced by my advisor and I remember he once told me: "The most important course you take at the university is the writing class." He believed that no matter how smart you are, or how successful you would be in conducting your research, you still need to present your work in an organized way that everyone can understand. I agreed with his proposition, which is why I tried to design this in-class activity with some writing exercises. Perhaps, in the future, I would try to design these in-class activities in more interactive ways, such as having students to pick a topic they like, work on writing a sample abstract, and present it to the class. I believe that my students will enjoy these kinds of in-class activities more than reading and writing summaries in the engineering area.

In conclusion, I have learned how to adjust my class load, level of difficulty, and in-class activities, based on the students' feedback. Once I tried to encourage more in-class participation, students were not afraid to ask questions towards the end of the class. Although it was a very challenging task to design the class by

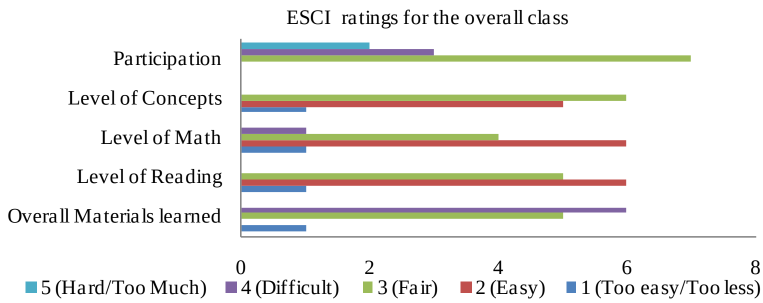

Figure 4. ESCI ratings for the overall class.

incorporating everyone's feedback, I certainly made my best effort to guide them learn throughout all five sessions. I believe regular evaluations in my future class will definitely help improve and sharpen my teaching skills.

7. Analysis and Discussions

First, I noticed from the beginning of the class, I was not familiar with my students' prior knowledge, and thus, I had overestimated their knowledge of mathematics. I discovered this problem in the in-class activity during the first week. The students came from different educational backgrounds, and some of them did not have adequate prior knowledge before taking my class. I had to change my teaching style. Thus, I began each class by reviewing some basic materials that I expected them to know and tried to spend more time on reviewing unfamiliar concepts. This helped my students to connect the new material easier with their prior knowledge. After I changed my way of teaching, the students started to pick up the new material without difficulty and they all had fun learning in this way.

Second, because this course was very flexible in the amount of lecture materials, there was no pressure as to "how much material" students should learn from my class. In other words, we do not need to pass on all of our knowledge to the students, but rather to inspire them in the field of science or engineering. As a result, I asked my students to do a class assessment before they left the classroom each time, and this helps me to adjust my topics accordingly for the following week. For example, before I started my first session, I asked my students to fill out pre-course surveys, so that I could better determine their abilities on performing these digital technologies. As a result, I saw that most of my students wanted to learn how to write computer programs. After I saw their comments, I changed the rest of my sessions so that they could have some experience with writing programs in C++. I learned how to change my class materials dynamically based on the students' feedback and abilities, which I believe was a valuable experience for me. I believe that the more feedback that my students provide, the better I can structure my lectures.

Moreover, I tried to foster more in-class participation for each of my sessions. For instance, I constructed a technology-supported environment to motivate my students' to participate. In addition, I asked students to pair up and do an activity together right after I finished my lecture. By doing so, I had made myself a creative instructor for designing these in-class activities. I believe that both ways are very helpful for students to activate participate in the class, to think critically, and to see how much they understood the newly introduced concepts. In other words, I consider this as the best way for students to absorb new material faster. As a result, I saw that my students tended to ask questions more frequently during these group activities, because many of them did not feel comfortable speaking in front of the class. This experience was very valuable for me since it allowed me to realize that students learn material more successfully through in-class activities.

Furthermore, my students like about my in-class activities in aiding their ability to learn a certain concept, my fair amount of course load that was adjusted on a weekly basis, and the level of difficulty that was altered constantly based on their weekly feedback. The ESCI chart reflected that the overall materials learned were average, and the level of concept, math and reading were all fair. The evaluations in this course have greatly helped me to figure out my strengths and weaknesses in my teaching career.

In conclusion, I especially think that getting feedback from the previous sessions helped me to organize my class materials and to design more interesting activities for the next session. In addition, obtaining student feedback has allowed me to assist students to learn new material more effectively. In other words, not only I teach my students class materials, but they also teach me on how to become a better instructor. The only way to become a good instructor is to engage in lifetime learning. The more feedback and suggestions I can obtain from the students, the better instructor I will be in the future, and that's the fundamental key for effective teaching and learning.

8. Conclusion

Having students to actively engage in the classroom stimulates their learning motivations, and makes the classroom experience more enjoyable. As a result, I have introduced my experiences in developing a technology-supported learning environment to increase students' learning motivations and achieve collaborative learning.

The first benefit of such pedagogy was that it helped me to become an excellent educator. I grew from an amateur to a much more experienced instructor, who could make a class more interesting and meaningful. I learned how to utilize the technology to create practical in-class activities to encourage more class participation and dynamically adjusting materials based on students' backgrounds. I truly believed that the time I spent on evaluating the students' feedback was a critical part, because their evaluations showed me how I could improve my teaching methods. In addition, I learned that continued self-assessment was an important key to becoming a better instructor.

Second, my pedagogy allows my students to become more active in the class, to obtain more learning knowledge, to increase their learning motivations, to pay greater attention in my class, and ultimately to simulate their interests in learning inside and outside of the class. As a result, it encourages students to engage more actively in the class and lead to greater learning in the classroom. In addition, once the students become engaged, instructors will become more motivated toward teaching.

Third, the benefit of such pedagogy is that in order to become a better instructor, I have to strive continuously to improve or adjust my teaching methods according to the students' reactions and suggestions to improve my overall teaching quality. Because students have different educational backgrounds, I have to change my teaching methods regularly to help students learn more effectively. For me, this is the most interesting and rewarding part because facing these different challenges allows me to obtain greater accomplishments. I learn that I must continually evaluate and improve myself to become an excellent instructor who can help students to learn better, more effectively, and more thoroughly.

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Construction of Assistive Technology for Blind Women: Handbook on Behavioral Contraceptive Methods

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Abstract

It notes the need of searching for technologies and strategies that encompass the universe to be reached, considering the peculiarities of each customer. Thus, there is a need to develop educational technologies on sexuality in accessible formats and inclusiveness to promote health to the blind people. This study aimed to describe the construction of an assistive technology for blind women on sexual and reproductive health, with a focus on behavioral contraceptive methods. This is a study of development of assistive technology on sexual and reproductive health. Results presented in two categories: 1) content and 2) appearance. The construction of educational textbooks for blind people is to facilitate the lives of these people.

Keywords

People with Visual Impairment, Contraception, Natural Methods of Family Planning

1. Introduction

Disability is defined as problems in body function or structure, with a significant deviation or loss of structure or psychological, physiological or anatomical function (World Health Organization, 2004). People with disabilities include those who have long-term of physical, mental or intellectual nature, which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others. There are about 650 million people with disabilities around the world (Factsheet on Persons with Disabilities, 2012), and 191 million impaired people in Brazil, of these 506.377 are visually impaired people (The Brazilian Institute of Geography and Statistics, 2009).

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The visually handicapped person is one who presents loss or abnormality of visual function; there are two types: low vision and blindness. Low vision is a severe decrease in the ability to see far or near, or by having a restricted visual field. Blindness is the complete loss of vision and ranks on: congenitally blind (people who have never seen); early blind (those who have lost their vision at one year and a half old); and late blind (who acquired blindness after one year of age) (World Health Organization, 2004). The focus of this study is to blind customers, which need health care equally to all people.

Blind presents difficulties in accessing health information, especially in sexual and reproductive health, as it requires different approach. Sexuality is one of the dimensions of the human being which covers gender, sexual orientation, gender identity, eroticism, emotional involvement, love and reproduction (Oliveira & Pagliuca, 2011; Denise, 2014).

Society does not realize in the blinds the needs of emotional and sexual attachment, limiting their life chances and creating relationship of "non-person" for the development of sexuality (Maia & Ribeiro, 2010). Blind people feel the need to talking about sexuality and have the right of access to information in ways that are understandable. This right guaranteed in the care of family planning that consisted of educational activities for selection and discussion of contraceptive methods available, aiming to free choice and responsibility on the part of the woman and/or couple (Dombrowski, Pontes, & Assis, 2013).

There are several methods of family planning. Among contraceptive methods (MACs) (Dombrowski, Pontes, & Assis, 2013) available, there are the behavioral methods. These are known to require individuals' periodic abstinence from vaginal intercourse during the fertile period, if one does not want to get pregnant; if desired, it is recommended to have a relationship at that time. This method depends on the recognition of ovulation and fertile period to be successfully accomplished. The main disadvantage is that it prevents sexually transmitted diseases (World Health Organization, 2013).

Behavioral methods include coitus interruptus and the awareness methods of fertility that include the basal body temperature (BBT), cervical mucus or billings, and the table of ogino-knauss. These methods, therefore, favor the exercise of autonomy.

The blind costumers present demand for information about their health condition, either on health promotion, prevention, diagnosis or treatment. One strategy used by nurses to attend in these situations is to develop educational materials, as manual.

The use of educational handbook as a help tool, based on scientific knowledge, can promote health and at the same time, make life easier for people. Reading manuals helps patients, families, and neighbors during learning and thus stimulates self-care, and makes them understand the process of health and disease. The construction of educational textbooks for promotion and health education brings important contributions as an educator and educational support for learners.

From the foregoing, it finds the need to seek technology and strategies that encompass the universe to be reached, considering the peculiarities of each customer. Development studies of assistive technology are intended to develop resources and services that will help promote independent living and inclusion of people with disabilities (Bersch, 2012).

Thus, there is a need to develop educational technologies on sexuality in accessible formats and with inclusiveness to promote health to the blind people. Given this context, the objective was to describe the construction of an educational manual for blinds on sexual and reproductive health with a focus on behavioral contraceptive methods.

2. Method

This is a study of development of assistive technology, in the form of an educational handbook, which describes the model-building of the manual, following concepts of universal design and assistive technology for the blind person, understanding that this is the most appropriate way to approaching its vertices.

Universal design includes projecting physical, social, and virtual environments in which all people, respecting their characteristics, may live with harmony, wellness and wholeness (Freire Jr., Arêas, Arêas, Silva, & Barbosa, 2013). Educational materials on health respecting this principle allow people with different access requirements to benefit from the same information, facilitating human interaction.

Building an educational manual requires development of project, which includes content and appearance, understanding and integrated in successive phases. The project set up objective and target audience to be addressed, this junction is given the theme and content, the audience certainly explains their topic of interest (Echer, 2005).

For preparation of the contents were consulted, in a systematic way, reliable sources of scientific literature; official documents and educational materials available in health services. The materials collected were critically read, blacklisted, organized by subject and selected to integrate content; important to select the essential information. The resulting text uses clear, objective and understandable language to wide range of people. Subsequently, should be reviewed regularly to keep its content updated (Echer, 2005).

When preparing educational materials for the blind, some characteristics of appearance must be met: principles of universal design, inclusive figures, suitable sources, footnotes and physical structure (Bersch, 2012).

3. Results and Discussion

3.1. Building the Manual

The intent of Universal Design is not driving a technology only for the needy, but for all people. The goal is to promote the creation of inclusive products for people with disabilities, avoiding that feel excluded from society (Freire Jr., Arêas, Arêas, Silva, & Barbosa, 2013). The principles of Universal Design should be followed in the construction of any educational manual. Thus, it can reach to population and not only a small portion of this, people who know braille spelling.

The results will be presented according to the construction of the technology in two categories: 1) contents and 2) appearance.

3.1.1. Category 1: Content

Initially, there was the identification of the target audience, made gathering information that had an interest in learning through informal conversations and interviews and the best format to addressing this issue.

At first, there was the search for the manual's content. Educational materials available on this topic in health services driven to the general population were collected. Then, was performed a bibliographic search for obtaining scientific articles and texts for theoretical background. The diversity of materials allows the selection of those considered accessible and understandable to the population to be benefited.

When selecting the contents of the manual there were valued subjects which watched the main doubts among users. The selected information should assist the customer's self-care and avoid imposing patterns of behavior and attitudes. It is deemed important to selecting the information that is really necessary to be included in the manual, because this needs to be objective, simple and direct, can be extensive and complex. It needs to be easily understood, with brief reading that encouraging people to read till the end.

The content presented sought to be well written and easy to understand, to engaging the reader and cause learning, autonomy leading to these clients to foster their decision making and thus promote health. So the contents of this manual should be planned, accurate and relevant enabling effective communication in health (Gozzo, Lopes, Prado, Cruz, & Alameira, 2012).

It was found a notebook on primary care: sexual and reproductive health and a small notebook titled sexual and reproductive rights and contraceptive methods, both published by the Ministry of Health (MOH). Then it was decided to adapt their contents to build the manual.

The manual was divided in two parts: introduction and development. In the introduction contains the presentation, the theme and goals. The development addresses the benefits of the practice to the individual, the availability of elements, professional recommendations and scientific evidence (Gozzo, Lopes, Prado, Cruz, & Alameira, 2012).

The contents of the manual has been exploited since the cover; later in the presentation, with elucidation of the origin of the chosen theme, the topics and objectives of the work, which are to provide information in a clear and appropriate manner to the blind people, and serve as the basis for health professionals at the time to offer advice or perform health education to that particular group. It has a summary with the list of the discussed topics, divided into sections, with their pages.

The concepts and considerations should be presented in a logical order, the information is cleared with examples and it is recommended to use only texts necessary for understanding, not use too many arguments that can confuse the reader or tire him. Use positive actions, emphasizing what should be done by the reader, and what should not be done, as well as emphasizing the benefits after reading.

In the first part, entitled "The body of the woman", the woman's reproductive system was described, presenting the female anatomy, the internal and external organs and their functions. External and internal genitals were shown in figures representing each region described. A step by step description of the exploitation of figures aimed to facilitate blind to the knowledge of what is groping and show the proper way to explore the figure to understand the subject matter.

The chapter "How to get pregnant" discusses the physiology of fertilization. In this, it describes how pregnancy occurs, when it manifests the woman's fertile period, the route taken by sperm to reach the egg and zygote formation occurs. After this explanation, it drew in ink and dotted touch the figure of the female reproductive tract, with the path that runs along the sperm to reach the egg. Understand the female reproductive anatomy and physiology is essential to understand the functionality of the behavioral contraceptives.

"Talking about contraceptives," begins the explanation of what these methods, we describe the currently existing methods and criteria to choose the one that fits the lifestyle of the reader. Thus, to proceed to the last part of the manual, you can easily understand the differential behavioral methods.

Finally, behavioral list is contraception. Presents its definition, we show the benefits and harms, about each type of behavioral method and its peculiarities is explained. For this, the text followed the order: table, cervical mucus, temperature, and method of withdrawal. In the description of each method discussed is a sub-item on the instructions and an example.

The method of table requires the observation of several menstrual cycles to determine the woman's fertile period. The adoption of this method requires discipline, knowledge of the functioning of the body and close observation of the woman. This chapter presents a model for building a tactile blind person table in a braille calendar she record the menstrual cycle. The method Cervical Mucus is based on the determination of self-fertile by observing the change of the consistency of the cervical mucus, and the sensation of dampness in the vagina throughout the menstrual cycle period. To understand the aspects of the mucus was used as an example egg that has texture like mucus.

The basal temperature is based on the changes that the female hormones cause the body temperature during the menstrual cycle for this assessment blind woman uses audible thermometer. Basal body temperature is the body temperature at rest. The withdrawal method involves the responsibility and the control of man, since it should withdraw the penis from the vagina before ejaculation. Each of these methods has its instructions for use described and accompanied by tactile figures related to each specific method.

The language used is extremely important and has to be clear and objective. Indeed, the purpose of the construction of the manual is to provide guidance to clients, families, neighbors, friends, so indispensable simple language that can be understood by everyone, regardless of the level of instruction (Echer, 2005). It limited the use of jargon, technical and scientific terms. The content and language technologies addressed in health and educational materials should be appropriate according to the needs of the audience, respecting the culture and way of life of each.

3.1.2. Category 2: Appearance

To understand the goal of universal design, the appearance of the manual is available in Braille and ink simultaneously. Any figure in inclusive educational material should be described, *i.e.*, textual equivalence has thus, facilitating understanding by the visually impaired reader. Therefore the figures presented in the manual contained description in Braille and ink and preceding figures was touching explicit direction to them to understand them better. For example: "grope starting from the bottom, in the central region, which will touch the vaginal canal. Rising in the figure, will find the cervix, which separates the vaginal canal of the uterus. Further up is the uterus, which is all this central space to the top".

The use of pictorial features that convey a message can reduce communication barriers. Besides proposing readability and comprehension of text, illustration attracts the reader and explains the information (Gozzo, Lopes, Prado, Cruz, & Alameira, 2012). The number of six figures is limited to avoid overloading. These have embossed dotted contours. This type of printing is known as thermoform, held in graphical braille specialized printing this handbook Dorina Nowill, located in São Paulo. The figures were presented in real size, to avoid bias in interpretation.

When written in ink, it used the largest and capital sources for headings, subheadings highlighted in lowercase, but in bold, white paper written in black on the cover illustration was presented showing the theme, so the reader can grasp the main message.

There were avoided header and footer notes that confused the reader, making its reading interpreting the same as an integral part of the content. The physical structure of the manual presented black printing on white background; cover with images and attractive colors; binding to facilitate the handling of pages; actual size of A4 paper; forty-four numbered pages, so they don't become heavy and bulky.

At the same time, writing in Braille and tactile ink and drawing figures. Thus, universal design allows the use of the manual by blind and sighted. Among the purposes of the construction of affordable manual, are: guidelines to facilitate the blind consultations by health professionals; provide support to teachers in public and private school systems; promote health through health education, work in communities; clarify the doubts of the population as a means of consultation; obtain studies and research on this subject. The manual can be used individually or in groups.

4. Conclusion

Educational technologies intended to facilitate the knowledge of the target population. The construction of the manual took place to facilitate the learning of the blind people about sexual and reproductive health, since that portion of the population has presented difficulty to acquire accessible information on this theme. On the other hand, it is also a way to help the work of health professionals in queries and actions of health education of family planning.

The construction of educational manuals for blind people has taken place to make the lives of these people easier. The use of educational, illustrative and instructive manual contributes to a better learning. Users can receive guidance through the manual and walk the path best suited to follow. The use of manual in the teaching-learning process has been used since the schools until health queries. Assistive technology is another tool to make life easier for people with disabilities, and provide information about health promotion and self-care.

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Making Dioramas of Women Scientists Help Elementary Students Recognize Their Contributions

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Abstract

The STEM movement encourages girls to consider careers in science; however, for success, common misconceptions and biases need to be dispelled, while females' spatial thinking skills are developed. All students, both girls and boys, need exposure to the accomplishments of women scientists to appreciate their contributions and to envision females as successful scientists. This one-week study conducted during a summer day camp examined upper elementary student (n = 15; 7 females, 8 males) attitudes toward science, women in science, and the possibility of a science career before and after participation in learning about diverse accomplished women scientists and making a diorama showcasing the professional work and caring actions of one of the scientists. The efficacy of this project for upper elementary students, conducted during a summer day camp, is supported by pretest-posttest data and attitude surveys. The five-day class showed positive changes in student plans for a career in science and improved attitudes toward the importance of females becoming scientists. Directions for constructing dioramas, examples of student-made work, and creative scenes made with given craft items are provided.

Keywords

Student Attitudes toward Science, Women in Science, Dioramas, Spatial Skills, Science Careers

1. Introduction and Background

1.1. Fewer Girls Aspire to STEM Careers

A study undertaken by the American Association of University Women (Hill, Corbett, & St. Rose, 2010) ex-

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plored the reasons why so few women have careers in the science, technology, engineering, and mathematics (STEM) fields. Although both female and male students study mathematics and science in roughly equal numbers with equal achievement during their kindergarten through grade 12 years and are similarly prepared for science and engineering majors in college (Shettle et al., 2007), fewer women pursue these majors (National Science Foundation, 2009). At college graduation, men outnumber women in almost all science and engineering fields with women earning only 20% of the degrees in physics, engineering, and computer science (National Science Foundation, Division of Science Resources Statistics, 2008, data from Table 11). At the graduate education level, the university faculty level (Di Fabio, Brandi, & Frehill, 2008), and in the industrial workplace (Hewlett et al., 2008; Simard et al., 2008), women's science and engineering participation declines further.

The reasons why more females don't enter STEM fields are generally *cultural* (Hill, Corbett, & St. Rose, 2010). Current cultural structures include family differences in career expectations for daughters compared to sons (Leaper & Brown, 2008) and the lack of female science role models in schools and the media (Bettinger & Long, 2005; Fouad, Hackett, Smith, Kantamneni, Fitzpatrick, Haag, & Spencer, 2010). Negative stereotypes about girls' abilities to perform in mathematics and science still abound, lowering girls' aspirations for these career areas (Hill, Corbett, & St. Rose, 2010). A "growth mindset" in which a person believes one can learn new skills and improve is needed for girls to envision themselves as working hard, gaining competence, and eventually succeeding at challenging tasks (Dweck, 2006, 2008). Girls' internalized standards for self-performance in STEM subjects are higher than those of boys, with girls telling themselves they need to perform at *exceptional* levels to succeed (Correll, 2004). Additionally, spatial ability has been identified as a necessary foundational skill area for success in the STEM fields (Downs & DeSouza, 2006).

Spatial ability is one area, though, in which men and boys currently outperform females (Sorby & Baartmans, 2000; Voyer, Voyer, & Bryden, 1995). However, females can quickly catch up if given the opportunity to exercise those skills (Sorby, 2009). Sorby, a researcher who has been examining male-female spatial ability and ways to improve spatial skills for many years, "sees well-developed spatial skills as important for creating confidence in one's ability to succeed in math and science courses and ultimately in a STEM career, because spatial skills are needed to interpret diagrams and drawings in math and science textbooks as early as elementary school" (Hill, Corbett, & St. Rose, 2010: p. 56).

Other cultural biases affect girls' entry into and persistence in STEM fields. A study of high school students' attitudes toward science careers (Miller, Blessing, & Swartz, 2006) found that females considering a science career were more interested than males in the people-oriented aspects of that major. The notion, often subconscious (Nosek, Banaji, & Greenwald, 2002), that STEM fields are "masculine" impacts girls' decisions about careers. Many people judge women in the STEM fields as less competent than men until they have shown themselves to be clearly successful, at which point they are often viewed as less likable (Heilman et al., 2004; Archer, DeWitt, Osborne, Dillon, Willis, & Wong, 2012). A way that a successful woman in a predominantly male field could maintain being positively viewed by colleagues was to strongly exhibit traits of being understanding, caring, and compassionate (Heilman & Okimoto, 2007). Early instruction dispelling these stereotypes and biases can positively affect the number of females who choose and complete careers in the STEM fields. Exposing elementary students to females' achievement in STEM areas can "affect girls' performance, how they judge their performance, and their aspirations" (Hill, Corbett, & St. Rose, 2010: p. 90).

1.2. The Women Scientists Diorama Project

This model-construction and science learning activity project focused on changing boys' and girls' ideas about women's contributions to science by exploring the lives and work of eight notable women scientists through making a three-dimensional diorama. The investigators asked, "How will making a diorama of a woman scientist's life and work, and hearing about the lives of other female scientists through electronic slide presentations affect elementary student attitudes toward women in science and a science career in general?" The study took place during a week-long summer day camp in which 15 students entering grades 4, 5, and 6 attended the women scientist diorama class for approximately 45 minutes each day.

The diorama-creation activities were designed to maximize positive impact on the elementary student participants in the following ways:

- Eight female scientists were highlighted to focus attention on women's proficiency and contributions to science. Contemporary or near contemporary women scientists were chosen, rather than historic women scientists such as Marie Curie, so that students would become familiar with modern role models. Two previous studies (Mead & Métraux, 1957; The Research Business, 1994) indicated that most high school students were familiar only with famous men of science like Einstein, Bell, and Newton. The earlier study (Mead & Métraux, 1957) recommended that science teachers focus more on tales of what scientists do in their daily work. The cultural significance of women scientists' work was highlighted, as Munro and Elsom (2000) found that science teachers tend to emphasize the instrumental value of scientists' work to the advancement of science, causing students to surmise that science is only of value to scientists with little impact on everyday life.

- The diorama work presented many spatial problems such as: how to make a pop-out scene, how both the interior and exterior of a building could be portrayed in a diorama that opened like a book, arrangement of images, and making of miniature furnishings. This three-dimensional work supported development of spatial skills important to success in STEM fields (Root-Bernstein & Root-Bernstein, 2013).
- Women scientists were chosen to present a racially diverse group of scientists working in different areas of science with a variety of scientific, personal, and social challenges. The number of minority students pursuing STEM careers is small, partly because these students have less access to advanced science and mathematics coursework in high school (Perna et al., 2009). Another reason minority students do not pursue STEM fields is the lack of a network of support leading to self-efficacy in science (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011). Because many minorities are not aware of minority role models in science (Johnson & Watson, 2005), we chose a diverse group of eight women scientists. Mary Leakey and Dorothy Crowfoot Hodgkin were White British women, Barbara McClintock was a White American; Lisa Perez Jackson and Patricia Bath are African Americans; Tolani Francisco and Joan Esnayra are Native Americans; Ellen Ochoa is a Hispanic American.
- The electronic slide show presentations designed by the teachers told about many aspects of each scientist and her work, including ways she was a caring person to counteract the stereotype that successful women in science are cold and uncaring (Heilman et al., 2004).

1.3. Standards Addressed by the Women Scientists Diorama Project

Many crosscutting concepts from the Next Generation Science Standards (Achieve Inc., 2013) were addressed by the women scientist diorama project. **Table 1** presents these and describes how information provided to students about the women scientists supported the standards.

The Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993), in discussing the "Scientific Enterprise, state "By the end of the 5th grade, students should know that science is an adventure that people everywhere can take part in, as they have for many centuries" (p. 16), and, "By the end of 8th grade, students should know that until recently, women and racial minorities, because of restrictions on their education and employment opportunities, were essentially left out of much of the formal work of the science establishment; the remarkable few who overcame those obstacles were even then likely to have their work disregarded by the science establishment" (p. 17).

The state in which this study took place, Iowa, has education standards for all grade levels (Iowa Department of Education, 2013). In the area of 21st Century Skills, at the grade 3-5 level, the Iowa Core states: "Students will choose a career area that interests them, and produce a list of skills, habits, and duties that assure success in that career area." Learning about the lives of women scientists will enlighten students as to what they actually do in their jobs and the required skills and dispositions necessary for being scientists.

2. Method

2.1. Participants

This lesson sequence was conducted with a group of 15 elementary students (7 female, 8 male; 11 White, 2 Black, 2 Hispanic; 5 entering fourth grade, 6 entering fifth grade, and 4 entering sixth grade) during a daily 45-minute class at a weeklong summer day camp. This project was approved by the Human Subjects Committee of the overseeing university and the day camp directors. All participants and their parents provided written consent for data and photographs to be used in the study.

Table 1. Crosscutting concepts from the 4th and 5th grade next generation science standards addressed by the women scientists diorama project.

Crosscutting concept	How concept addressed by the women scientist diorama project
Connections to engineering, technology, and applications of science.	
Influence of science, engineering and technology on society and the natural world.	
People's needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1)	Joan Esnayra founded the psychological service dog society to provide assistance to veterans and others with posttraumatic stress disorder and other mental issues.
Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-5-ETS1-2)	Patricia Bath improved the technology of mechanically grinding away the clouded cornea to treat cataracts by inventing the Laserphaco probe, a faster, more accurate and less painful approach to cataract removal.
Interdependence of science, engineering, and technology.	
Knowledge of relevant scientific concepts and research findings is important in engineering.	Astronaut Ellen Ochoa earned degrees in science and engineering, working on optical systems and robotics for the space program before becoming the director of the Johnson Space Center.
Connections to nature of science	
Science is a human endeavor.	
Most scientists and engineers work in teams.	Barbara McClintock worked with a team of botanists from South America to determine the evolution of maize.
Science affects everyday life.	Lisa Perez Jackson observed the inequities of clean air and water for people in impoverished communities; therefore, she worked to develop environmental protection agency regulations.
Scientific knowledge assumes an order and consistency in natural systems	
Science assumes consistent patterns in natural systems.	All of the women scientists examined patterns in some way to solve the problems they encountered. For example, crystallographers study X-ray diffraction patterns to determine arrangement of atoms.
Patterns	
Similarities and differences in patterns can be used to sort and classify natural phenomena.	Dorothy Crowfoot Hodgkin examined X-ray diffraction patterns to determine the crystal structure of vitamin B-12 and over 100 other compounds.
Similarities and differences in patterns can be used to sort and classify designed products.	Mary Leakey developed a classification system for the stone tools she excavated.
Systems and system models	
A system can be described in terms of its components and their interactions.	Veterinarian Tolani Francisco worked within the natural interactive system of cattle and bison to determine the transmission of infectious diseases.
Cause and effect	
Cause and effect relationships are routinely identified, tested, and used to explain change.	Barbara McClintock conducted genetic experiments with corn, observing the colors of corn kernels to determine her Nobel Prize-winning model of jumping genes.
Scale, proportion, and quantity	
Natural objects exist from the very small to the immensely large.	Many of the scientists used microscopes (micro scale) or X-ray diffraction (nano scale) in their work; others explored large animals, industrial complexes and outer space (immense scale).
Energy and matter	
Energy can be transferred in various ways between objects.	Lisa Perez Jackson has led the Apple Corporation to develop renewable energy sources for their facilities.

2.2. Study Design and Setting

The study took place at a one-week summer music day camp held on the campus of a university and sponsored by the music department of the university. The theme of the music camp was "Full STEAM Ahead," meaning

STEM (Science, Technology, Engineering, and Mathematics) education with integrated arts activities (the "A" in STEAM). Over a hundred students attended the K-12 camp. Each student chose an elective course for early morning that was somehow related to the camp's theme. The dioramas of women scientists' course was one of those electives and fit well with the theme because of the focus on learning about scientists through the artwork of a three-dimensional diorama.

The study had a simple pretest-posttest experimental design with all students participating in the lesson activities. Students attended an approximately 45-minute lesson each of the five days of the camp and participated in music-related activities of the day camp the rest of the week. They responded to a pretest on the first day, an attitude survey on Day 2 and Day 4, and a posttest with two additional insight questions on the last day. The outline of the daily lessons is shown in **Table 2**.

2.3. Study Instrumentation

A short pretest-posttest attitude survey of ten items to which students responded by circling "really disagree,"

Table 2. Plan for teaching the dioramas of women scientists lesson unit.

Day	Activity	Time
1	Pretest administered.	5 minutes
	Who am I? Ice-breaker game. Students play game in which the name, photo, and work topic of a well-known scientist is taped to each student's back (e.g., Marie Currie, Albert Einstein). Students ask a "yes-no" answerable question to each classmate to discover the identity of the scientist.	5 minutes
	Painting. Students receive a diorama base and paint the inside with acrylic paints.	20 minutes
	Scientist information. Students listen to two slide show presentations about the life and work of women scientists: Mary Leakey (paleontologist and archaeologist) and Barbara McClintock (corn geneticist).	15 minutes
2	Icebreaker game. Students play the "Who am I?" game again with a different scientist taped to back.	5 minutes
	Painting. Students paint the outside areas with acrylic paints.	20 minutes
	Cutting. Students receive about 5 pages of color images for their chosen or assigned scientist and cut them out. Scientist Information. While cutting out images, students listen to two more presentations about scientists: Ellen Ochoa (shuttle astronaut) and Patricia Bath (ophthalmologist).	20 minutes
	Day 2 survey administered.	5 minutes
3	Diorama construction. Students glue the front of the face image to cardboard, cut it out again, and then glue the bottom inch of it to the upper front of the box so that the scientist's head stands upright above the box. They then glue the matching back side to the back of the face so that the bottom inch of it is glued *inside* the box front panel.	10 minutes
	Scientist information. Students listen to two slide show presentations of scientists: Dorothy Crowfoot Hodgkin (chemist and crystallographer) and Tolani Francisco (large animal veterinarian).	15 minutes
	Diorama Construction. Students work to glue images to the front of the box to decorate the building and to label the box with the scientist's name. Then they begin working on the inside of the building and the opposite scene of the scientist working.	20 minutes
4	Scientist vocabulary game: Students play a new game in which each student is given a scientific career term such as "environmentalist" or "crystallographer" and they must find the classmate with the corresponding definition of the scientist term.	5 minutes
	Students continue decorating the sides of their dioramas with information and images. Students listen to the final two slide show presentations about women scientists: Joan Esnayra (Geneticist) and Lisa Perez Jackson (Environmentalist).	15 minutes
	Each student receives an identical set of ten craft items from which to construct a scene related to his or her scientist, using all of the materials. They first generate several ideas related to the scientist, then choose one and begin to construct it. The scene is glued to the back of the box.	20 minutes
	Day 4 survey administered.	5 minutes
5	Diorama completion. Students work to complete all parts of the diorama including the creative activity on the back panel.	20 minutes
	Final Game: Students who have completed their dioramas play a simplified whiteboard version of Wheel of Fortune® with woman scientist-related puzzles; other students continue working on their dioramas.	15 minutes
	Posttest with two additional questions about insights administered.	10 minutes
	Diorama display. Finished dioramas are put on display for parents as they pick up students at the end of the week-long day camp. Students take their dioramas home.	

"kind of disagree," "neutral," "kind of agree," or "really agree" was developed to measure student attitudes during the project. These items were scored from "1" for "really disagree" to "5" for "really agree." The first three items were taken from a large scale market research survey conducted in the United Kingdom for the Institute of Electrical Engineers (The Research Business, 1994): "Science is interesting," "Science is useful for jobs," and "Science is easy." The fourth item measured students' personal ideas about a science career: "I plan to have a career in science." The fifth item addressed attitude toward science's cultural usefulness: "The work of scientists improves our lives." The final five items were created to measure important concepts related to women in science. These items were: "It is important for women to become scientists," "Females do as well as males in science," "Females have made important science findings," "Women scientists can help others through their science careers," and "Women in science can make science more caring."

Both pretest and posttest requested the participants to list historic or living women scientists and the areas in which they worked. The posttest contained two additional open-ended questions: "What did you learn about women in science that surprised you?" and "What new ideas or feelings do you have about science now?"

2.4. Materials and Equipment for the Dioramas of Women Scientists

The following list of materials and equipment was used to create the dioramas: an empty cardboard food product box for each student approximately 7 × 7 × 1.5 inches (about 18 × 18 × 4 centimeters) in dimension or larger; a smaller empty cardboard box, approximately 4 × 6 × 1.5 inches (about 10 × 15 × 4 centimeters) for each student (attached to front of larger box as a building); white copy paper for covering the boxes to make the papier-mâché base (recycled paper printed on one side may be used; place printed side down); scissors; white craft glue (Aleene's Original Tacky Glue is thick and effective, but any brand will work); canvas drop cloths or paper to protect table tops from glue (it is water-soluble, but takes effort to scrub off) and acrylic paint; paint brushes; white acrylic gesso (provides an excellent surface for painting and stiffens the box); acrylic paints of many colors (these non-toxic paints rub off skin, but are permanent on clothing once dry; tempera paints are not recommended—glue makes the paints wet again when the paper images are applied); paint cover-ups for students (the teachers provided large t-shirts that students wore to protect clothing); images and text explanations or labels printed in color on cardstock (the teachers made a PDF file of sized images with text and printed them on cardstock at a copy shop; soluble ink-jet images are not recommended as drops of glue make the ink run); small, cube-shaped pieces of stiff sponge-like foam packing material or Styrofoam for making the pop-out parts of a photographic scene of the scientist working; various small artifacts related to the chosen scientists' work to be attached to the box (e.g., stone tools, corn kernels, crystals, rocks, fossils, small animal figures, toy doctor tools); one identical set of ten items for each student for the creative activity glued to the back of the diorama.

2.5. Procedures for Making the Dioramas

The procedure for making the diorama bases is shown in **Figure 1**. The four teachers (a professor and three doctoral students majoring in curriculum and instruction) prepared the diorama bases, example dioramas, and pages of images before the five-day class began so that students would be able to complete the dioramas in the given time. The professor has made other diorama projects with elementary students and they were able to prepare the diorama bases. Readers should consider having upper elementary students make their own diorama bases (a one to two-hour task) if time permits.

The final creative activity involved making a scene on the back panel of the diorama related to the scientist's life or work by using all ten pieces of an identical set of given items. The items we used are shown in **Figure 2**. The set consisted of 1) a red speckled cardboard frozen food tray, 2) a yellow fuzzy chenille stick, 3) a white cardboard piece of packaging material, 4) a spherical gold pompon, 5) a wooden Popsicle stick, 6) a six-inch piece of pink grosgrain ribbon, 7) a 3 × 2 inch (about 8 × 5 centimeter) piece of green glitter sheet foam, 8) a small yellow envelope, 9) a strand of five plastic shamrocks molded onto a string cut from a necklace, and 10) a small plastic branch with three fabric leaves.

3. Observations and Discussion

3.1. Student-Made Dioramas

Students were thoroughly engaged in the work of making their dioramas. **Figure 3** illustrates students strongly

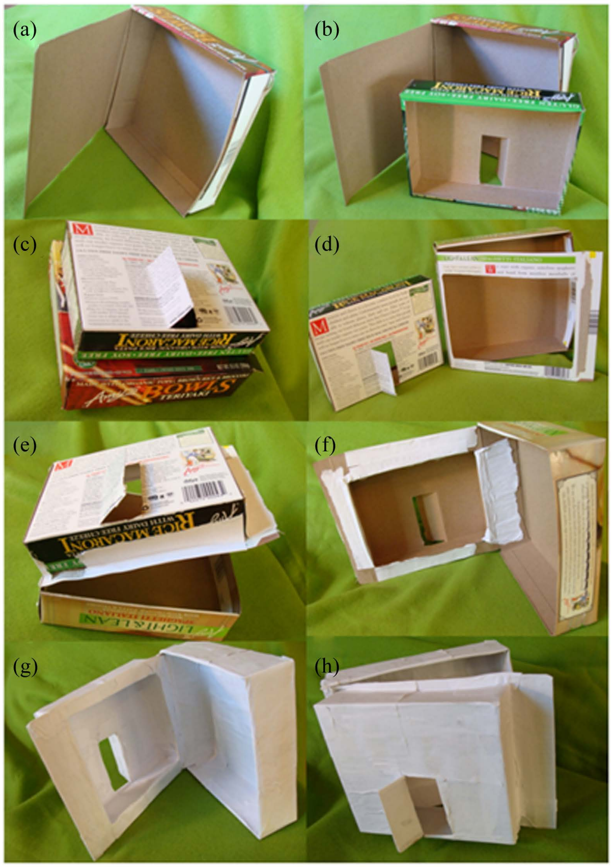


Figure 1. Steps in making a diorama base. The diorama base requires two boxes: a cardboard food product box that is approximately 7 × 7 × 1.5 inches in dimensions and another smaller box approximately 5 × 6.5 × 1.5. (a) Cut the large box so that it opens like a book. Add additional cardboard to the front flap edge (about 0.75 inch) so that the front flap does not fall into the box; (b) Cut the back side off of the smaller box and cut a door in the front panel; (c) Place the smaller box on top of the front of the larger box. Trace the rectangle of the smaller box onto the front panel of the larger box; (d) Cut out the rectangle; (e) Position the smaller box on the front of the larger box over the rectangular hole. Use glue-coated (on one side) torn pieces of white copy paper in a manner similar to tape to attach the smaller box to the front of the larger box. Use the glue-coated paper to "tape" all around the small box, securing it to the front of the box; (f) Use glue-coated torn paper pieces to "tape" the smaller box to the front panel from the inside. The glue-covered pieces should extend from the back of the front panel to the inside of the smaller box. Let dry a few minutes, pressing the paper so that it dries correctly; (g) Cover the entire inside of the large and small boxes with torn pieces of paper covered with glue on one side. Fold the white glue-covered pieces over the edges of the sides of the box and overlap them somewhat; (h) Cover the entire outside of the two boxes with torn, glue-coated pieces of paper. The paper should be folded over the edges of the box to form a continuous papier-mâché surface. Press on the paper and flatten or gently shape the box as it dries so that it is fairly flat with right angles. After the glue dries, coat the box on all sides with white gesso acrylic paint. This is a thick undercoat that stiffens the box and forms an effective surface for acrylic paints.

engaged in their work. **Figures 4-9** present examples of the student-made dioramas. The first step during class of painting the boxes was exciting for most of the students. Many painted parts of the box different colors; some students added designs. When deciding where to place the images and information, some students relied heavily on the teacher's example diorama, but others wanted to make their dioramas unique. All students had to make adjustments because of the varying dimensions of the individual boxes. This proved beneficial because it forced students to be creative in their placement of images and text. **Figures 4-6** refer to dioramas of the same four women scientists, while **Figures 7-9** pertain to a second group of four women scientists. **Figure 4** and **Figure 7**

Figure 2. Ten given items used for the creative activity.

Figure 3. Girls and boys focused intently on diorama work.

show the fronts of dioramas; **Figure 5** and **Figure 8** display the interiors of the buildings on the front, and **Figure 6** and **Figure 9** show the three-dimensional pop-out scenes of the woman scientist working. After gluing images and information on the box front and narrow sides, students began the three-dimensional scenes of the box interiors. Students expressed enjoyment as they created this spatial effect within their dioramas. Many worked tirelessly to place each piece precisely, giving the best effect. This work was intense for many students, and some had difficulty leaving the project at the end of the class period. When students returned the next day, they immediately started work on the projects, showing their investment in the project.

3.2. Pretest-Posttest Results Concerning Attitude Statements

Cronbach's alpha, a coefficient of internal consistency of items on a test or survey, was used to estimate the

Figure 4. The fronts of the first set of student-made dioramas. (a) shows corn geneticist Barbara McClintock and the Cold Spring Harbor Laboratory at which she did much of her work; (b) features astronaut Ellen Ochoa with the space shuttle Discovery; (c) pictures large animal veterinarian Tolani Francisco with an animal hospital center; (d) shows ophthalmologist Patricia Bath and the UCLA Medical Center at which she worked.

Figure 5. Interiors of the structures depicted on the cover of the dioramas of set 1. (a) shows the interior of Barbara McClintock's laboratory with black lab tables, a microscope, notebooks, and keys; (b) shows the shuttle in space (with Ellen Ochoa aboard), traveling around earth; (c) illustrates the animals being served by Tolani Francisco; (d) depicts Patricia Bath in her white lab coat at the medical center.

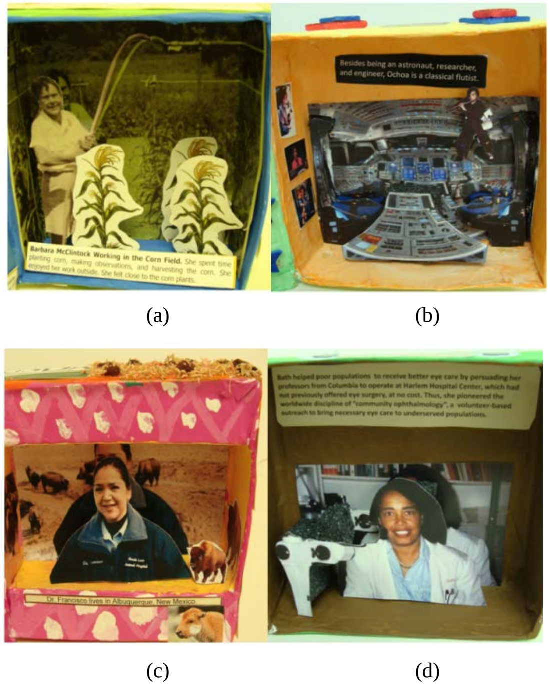


Figure 6. Three-dimensional pop-out scenes showing the scientists of set 1 at work. (a) illustrates Barbara McClintock watering plants in an experimental corn field; (b) shows Ellen Ochoa playing her flute inside the space shuttle; (c) shows Tolani Francisco thinking about the bison's disease; (d) depicts Patricia Bath with ophthalmology equipment.

Figure 7. The fronts of the second set of student-made dioramas. (a) shows environmentalist Lisa Perez Jackson and the headquarters of the Environmental Protection Agency in Washington DC; (b) shows the Olduvai Gorge Site Museum in Tanzania that Mary Leakey initiated; (c) is Yaqui tribe Member Joan Esnayra with adobe housing. (d) features Dorothy Crowfoot Hodgkin and multi-faceted view of a building from Oxford University.

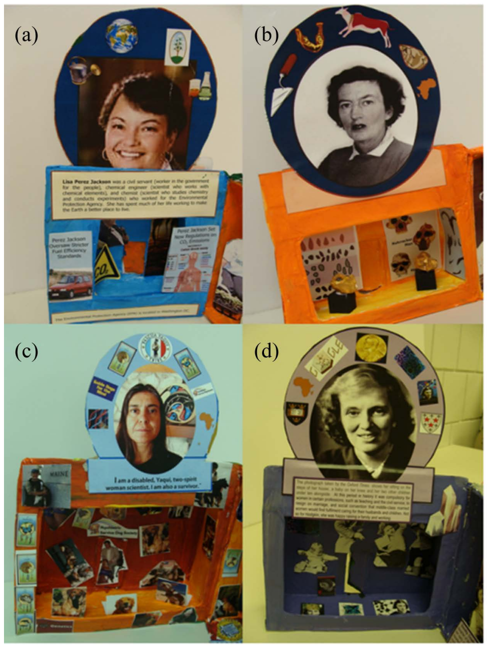


Figure 8. Interiors of the structures depicted on the cover of the dioramas of set 2. (a) shows some of the accomplishments of Lisa Perez Jackson while she was the director of the Environmental Protection Agency; (b) shows part of the interior of the Olduvai Gorge Museum containing archaeological and paleontological items from the dig. Two large Australopithecine skulls are mounted on black pedestals; (c) shows the kinds of service animals that are a part of the Psychological Service Dog Society which Joan Esnayra founded; (d) shows Dorothy Hodgkin and her children as well as two of the stamps issued in her honor.

Figure 9. Three-dimensional pop-out scenes showing the scientists of set 2 at work. (a) illustrates Lisa Perez Jackson working with local volunteers to plant tomatoes at the Riverside Valley Community Garden located in Riverside Park, Harlem, New York; (b) shows the Leakey family at work scraping the rock layers in Olduvai Gorge to uncover fossils, skulls, and stone tools; (c) shows Joan Esnayra engaged in genetics work in her laboratory; (d) pictures Dorothy Crowfoot Hodgkin working in her X-ray crystallography lab at several stages of her life.

reliability of the attitude survey, which contained ten questions. Cronbach's alpha (which varies from zero to one) was 0.81 for the women scientist attitude survey used in this study. In interpreting this result, one should consider that, in general, the higher the number, the greater the internal consistency: a Cronbach alpha score greater than 0.70 is good and above 0.90 is excellent; therefore the Cronbach alpha score for the survey was certainly in the acceptable range (Cronbach, 1970). **Table 3** shows that students tended to agree (ratings of 3.5 to 4.5) or strongly agree (ratings > 4.5) with most of the statements on the pretest. The two exceptions were "I plan to have a career in science" and "It is important for women to become scientists," both of which fell into the neutral rating zone (2.5 - 3.5). Student attitudes toward these two statements in particular evidenced large positive effect sizes as a result of the class. Exploring the interesting personal stories of diverse women scientists through viewing electronic slide presentations and making dioramas seems to have positively influenced student attitudes.

On the posttest, students expressed greater agreement (mean scores > 3.5) with all of the statements except "Science is easy" and "Females do as well as males in science." The lessening of agreement with these statements may be because the struggles that many women scientists underwent to be successful were discussed in the class. For example, Mary Leakey lived in a tent in the African wilderness, spending day after day scraping the rock layers to uncover fossils, work that required a lot of self-motivation and patience. Barbara McClintock's theory of gene transposition was not accepted as applying to other organisms for many years, resulting in scientists ignoring or belittling her work. Additionally, she feared that she would not be promoted at the University of Missouri because she was female and had to find another research position. Joan Esnayra experienced a childhood of substance, physical, and sexual abuse. She struggled with mental illness stemming from these circumstances but was able to innovatively help others through service animals because she understood their positive psychological effects. She eventually realized her dream of being a scientist, working for the National Academies of Science. Patricia Bath had to overcome prejudices against women and African Americans as she advanced in her ophthalmology career, becoming an advocate for medically underserved populations. These stories of the hardships of women scientists made them more aware of the challenges women scientists may face.

Another aspect emphasized by the teachers of this class was the caring attitude of many women scientists. Previous research by Pauline Lightbody has shown that female students may not picture themselves as scientists because they don't perceive science as a feminine career focused on helping others (Lightbody & Durndell, 1996; Lightbody et al., 1996). Additionally, research by Munro and Elsom (2000) indicated that both male and female students perceive science as preparing only useful specialists that provide no useful cultural knowledge. Therefore, we decided to emphasize the caring aspects of the female scientists we highlighted and the societal impacts of their work. For example, the teachers presented information about how Lisa Perez Jackson enacted clean air and water laws to improve the environment of others and how Patricia Bath helped many people blinded

Table 3. Mean pretest-posttest attitude scores.

Statement	Mean pretest score	Mean posttest score	Paired *t*-test *p*-value	Cohen's *d* effect size	Effect size interpretation
Science is interesting.	4.20 (0.9)	4.40 (0.8)	0.19	-	-
Science is useful for jobs.	4.50 (0.9)	4.53 (0.7)	0.08	-	-
Science is easy.	3.47 (1.1)	3.20 (1.1)	0.22	-	-
I plan to have a career in science.	2.40 (1.3)	3.33 (1.0)	0.005	0.80	Large
It is important for women to become scientists.	3.20 (1.2)	4.13 (1.1)	0.003	0.81	Large
Females do as well as males in science.	4.47 (1.0)	4.33 (1.4)	0.08	-	-
Females have made important science findings.	4.07 (1.0)	4.40 (1.1)	0.09	-	-
Women can help others through their science careers.	4.36 (1.2)	4.40 (0.8)	0.50	-	-
The work of scientists improves our lives.	4.07 (0.8)	4.07 (1.2)	0.50	-	-
Women in science can make science more caring.	3.36 (1.0)	3.80 (0.9)	0.014	0.56	Medium

Note: Scoring of ratings: 1 = really disagree, 2 = kind of disagree, 3 = neutral, 4 = kind of agree, and 5 = really agree. Standard deviations are shown in parentheses. Effect sizes were calculated for *p*-values less than 0.05.

by cataracts to regain their vision. Women scientists' caring for animals was also highlighted. Examples included the concern that veterinarian Tolani Francisco had for her large animal patients, the affection Mary Leakey had for the charming African hyraxes that stole food from the dinner table, and Joan Esnayra's desire to help others with psychological problems through service animals. This approach resulted in a medium effect size change in student attitudes from pretest to posttest on the statement, "Women in science can make science more caring."

An open-ended question on the pretest and posttest asked students to name well-known women scientists. On the pretest no students were able to name a woman scientist and her area of work. On the posttest, students were able to recall an average of three names of women scientists and their correct corresponding areas of work.

3.3. Attitude Surveys from Day 2 and Day 4

Before the class started, the professor sent an email message to all participants explaining that assessment data would be collected to evaluate the efficacy of the project (participants had been made aware of the data collection when they registered for the course), providing short descriptions of the eight women scientists on which the class focused, and asking for each students' top three choices of the eight scientists. This allowed the teachers to assign scientists for the student dioramas so that all eight were addressed in the class. Although a title and short description of the class had been available at registration, a few parents had not realized that the course focused on *female* scientists and they replied that their sons were concerned about whether there would be other boys in the class and whether they might choose a *male* scientist. The professor responded that half of the class was male, but that the topic would remain *female* scientists, as it was important for everyone to become aware of the often-overlooked contributions of women to science. Some male students were somewhat apprehensive at the start of class, but after the game that focused on scientists of both sexes and the exciting opportunity to paint the three-dimensional diorama with acrylic paints, everyone settled in quite happily. No complaints were made about the female scientist focus during the week. In fact, as the week progressed, the interest and pride of the boys in the women scientists on which they were concentrating was apparent as they often bragged to classmates about the accomplishments of their particular scientist while working on the diorama. **Table 4** presents student ratings of creativity, enjoyment, and learning on the second and fourth days of class. Students were also asked to give two reasons for each of their ratings.

Student creativity and enjoyment of the course increased as students became more involved. Students felt most creative during the special activity designed to require creative thinking, the activity in which students made a scene using ten given craft items. However, there were other opportunities for students to work creatively. Each diorama base was somewhat different in size, as many different small boxes had been used to make the building on the front. Students, therefore, had to determine ways to fit the color images to the size and shape of box each had chosen. Arranging items on the panels of the box and in scenes was done individually, leaving room for creative expression.

The teachers observed that students were very engaged in the diorama work, especially the creative assignment of making something related to the scientist on the back of the box with the ten given materials. Twelve students stated that they used their imaginations to think of creative ways for using the given ten items as a reason for rating this activity high in creativity. Students expressed that they felt challenged, but were having a lot of fun completing the activity. This fits with the state of *flow* in which a person is challenged to use many available skills, resulting in a sense of timelessness, continuous flow of ideas, and deep satisfaction (Csikszentmihalyi, 1990). In fact, many students remarked that time passed very quickly when they were working on the dioramas.

Table 4. Student mean ratings of creativity, enjoyment, and learning on a scale of "1" to "10" with "1" being "low" and "10" being "high".

Day	Mean rating for creativity	Mean rating for enjoyment	Mean rating for learning
Day 2	6.9 (2.5)	7.9 (2.4)	6.6 (2.8)
Day 4	9.1 (1.7)	8.4 (1.6)	6.8 (2.7)

Note: Standard deviations are shown in parentheses.

In general, students found the diorama project very enjoyable. Students justified high enjoyment ratings by citing the fun of making a three-dimensional diorama and the challenge of using their imaginations to produce the creative scene on the back side. Students also referred to enjoyment of paint color mixing, paper image cutting, and glue work as highly enjoyable, particularly because they had few other opportunities for these types of activities. Teachers observed that students arrived each day ready to work on their dioramas. Sometimes it was difficult to get students to stop working and prepare to go to their next class. Students enjoyed the hands-on construction activities and expressed that they seldom have such opportunities at school. Many schools have eliminated arts-integrated model-making projects, replacing them with computer technology labs, or with more reading and mathematics lessons to prepare for high-stakes testing (Au, 2007; Spohn, 2008). However, a recent study found that students displayed more science content information through hands-on arts-integrated projects as compared to technology projects (Klopp et al., 2014).

Regarding science learning, students noted specific information about women scientists that they had retained. Ten students mentioned how the scientists had helped other people. One student remarked, "These people are really caring; I wish I could have known them." Five girls remarked that they were pleased to learn that female scientists are as capable as male scientists. A student working on a diorama of Ellen Ochoa was placing colorful red, white and silver stars on her diorama. She said, "All the scientists deserve stars because they are heroes in my eyes." A male student who was working on a diorama of a Nobel prize-winning scientist, asked the teacher for foam to separate the two sides of the medal he was gluing together so that the medal would look three-dimensional. He explained that the medal was an honor and he wanted it to be special for his scientist because she deserved it.

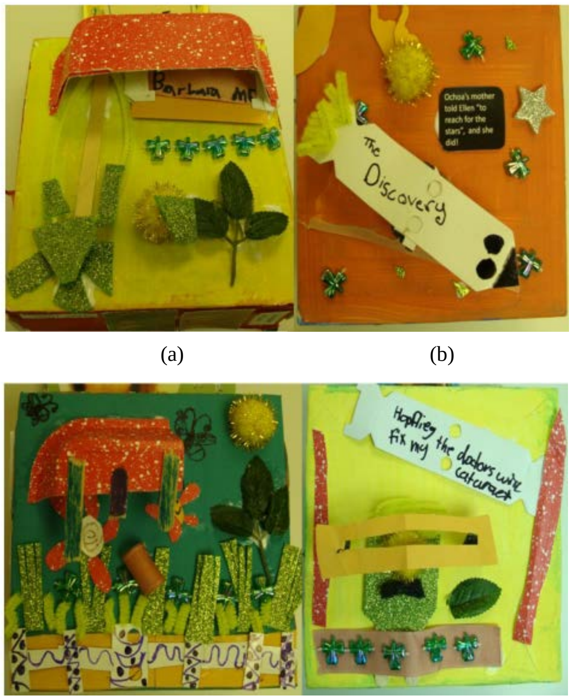
3.4. The Creative Activity

Figure 10 and **Figure 11** present some of the creative scenes made by students using the given set of ten craft items. After receiving the bag of items, students generated several possible themes for their scenes. Some students planned the scene carefully, while others took items one at a time and started construction. Most students had a couple of craft items that required more problem-solving to fit into the scene. However, almost everyone was able to incorporate at least parts of all ten items. Using all the provided items exercises the creative skill of *fluency* (generating many ideas). Another creative thinking skill is *flexibility*. This skill is evidenced when a student repurposes a material. For example, using the leaf as a tissue to wipe tears (**Figure 10(d)**) or part of a crystal pattern (**Figure 11(d)**), rather than as part of a plant, showed flexibility. *Elaboration*, attention to detail, was shown by the student who made the veterinary scene in **Figure 10(c)**. He added decoration to the white fence, drew butterflies, sketched flower centers, and fringed the glitter foam to make tall grass. Some students made their scenes three-dimensional, another creative trait. The student in **Figure 10** made a protruding red cover for a document; the student in **Figure 10(d)** had a pop-out ophthalmology machine; and the maker of **Figure 11(c)** showed a hair strand extending from the microscopic view. Many students used their imaginations to develop fantasy stories about their scenes. For example, the maker of the scene in **Figure 10(d)** imagined Ellen Ochoa traveling out of the regular shuttle orbit to "reach for the stars" by heading for the nearest star, the sun and the student creator of **Figure 11(b)** developed a story about his cave painting of a well-loved medicine man.

3.5. Additional Posttest Questions Involving Insight

At the end of the week, students responded to two additional questions on the posttest that called for their insights about the course. The first question was "What did you learn about women in science that surprised you?" Both female and male students provided the most frequent observation that women can be equal to men in science and help the world. The message that the investigators sent about women scientists being caring seemed to have been received. Several students named a specific accomplishment of a woman scientist that was studied such as Ellen Ochoa was Director of NASA, Barbara McClintock discovered jumping genes, Patricia Bath helped the blind, and Tolani Francisco worked on large wild animals. Students noted that many women scientists struggled against prejudice and unfair treatment, but diversity discrimination did not stop them. Another interesting response from one student was "they discovered things that I thought men discovered." This comment shows the previous mindset of the student that women had contributed little to science.

Responses to another question, "What new ideas or feelings about science do you now have?" revealed that many students now observed science as fun and exciting or that they had not enjoyed science previously, but



(a) (b)

(c) (d)

Figure 10. Example creative activity scenes glued to the backs of the first set of dioramas. (a) depicts a scene of the evolution of corn related to Barbara McClintock. Corn started out as a leafy plant with a small seed (on the far right near the bottom). Then, it has a tiny cob symbolized by the gold pompon in the middle. Finally, it has a large cob as shown at left with the chenille stick outlining the cob. The red tray is a cover that hides McClintock's secret genetic research on corn. The green shamrocks represent other green plants at the back of the corn field; (b) shows the Discovery Space Shuttle piloted by Ellen Ochoa as it soars with the sun and stars in the background; (c) depicts a scene related to large animal veterinarian Tolani Francisco. The white fencing at the bottom represents a corral for the animals. The rolled grosgrain ribbon represents a hay bale containing medicine for the animals. The butterflies have eye designs on their wings to scare away predators; (d) shows a man with a moustache who has cataracts receiving an eye examination from Patricia Bath (not shown).

now like it. Five students responded that scientists can help the world, again indicating that they now perceived successful women scientists as compassionate. These effects were highly desirable as student excitement about and positive regard for science are needed to encourage choice of careers in STEM fields. Four students also responded that they now believe that anyone, male or female, can become a scientist, in contrast to their earlier belief that all scientists are male. One 5-hour project is not likely to convert female students to planning a career in science, but it can be an effective link in the chain of events that leads in that direction.

4. Conclusion

Technology and standardized tests are an important reality in schools today, but educators must not forget that actively engaging students in hands-on creative activities is still a powerful learning tool necessary for well-rounded students. The imaginings our students participated in as they built the scenes of their dioramas are part of fantasy play, crucial for social, emotional, and cognitive development (Moyer, 2014). Imagining oneself in various careers, including its everyday work patterns, helps to prepare students for them and facilitates students being more patient and persistent (Bergen & Fromberg, 2009; Singer & Singer, 2006).

Students found the diorama project highly engaging, increasing their knowledge of and appreciation for the contributions of women scientists. Students were also reported to have an increased desire for science careers. Therefore, the authors strongly recommend that teachers consider implementing this project with upper elementary students. Although the preparation for the project required several hours of researching the scientists,

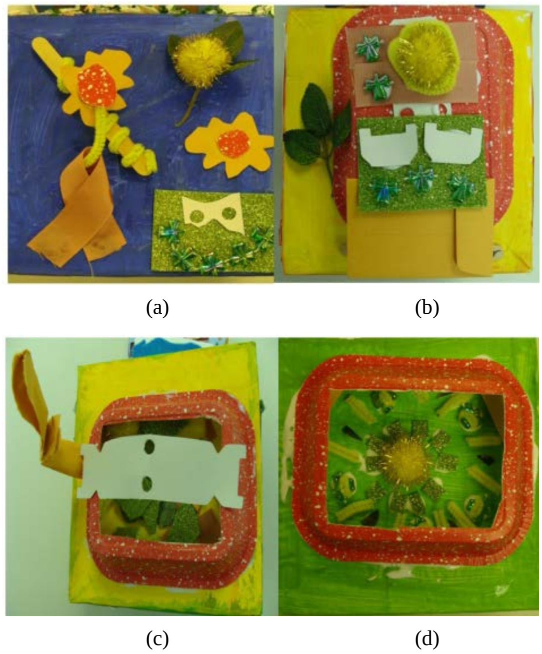


Figure 11. Second set of example creative activity scenes glued to the backs of the dioramas. (a) depicts objects related to Lisa Perez Jackson. At the left is a ribbon and flower symbolizing plantings that enrich the earth. At the bottom right is the green earth smiling because she is receiving care. The Popsicle stick has a vine entwining it to show the strength of nature; (b) is related to the work Mary Leakey did in publishing a book about cave paintings. This is a cave painting of the skull of a deceased tribal leader and medicine man. The yellow pompon represents a doctor's light on the forehead. The two eye sockets are the holes punched in white cardboard that is almost covered by a face mask of green glitter foam and yellow envelope paper. The green shamrocks are badges that show honors earned as a leader; (c) is a view of DNA through the microscope related to Joan Esnayra's work. The protruding yellow construction on the left is a magnified hair; (d) depicts a crystal diffraction pattern similar to those used by Dorothy Crowfoot Hodgkin.

preparing electronic slide shows about them, and creation of example dioramas, with more time allotted to the work for students, much of this effort could be shifted to them with increased student benefits. The next section explains how this might be done.

5. Extensions and Cross-Curricular Applications

The researchers were heavily constrained by the one-week day camp model in which teachers had about 45 minutes a day for five days with the students. The investigators would have liked to have had additional time so that students could examine and learn about the women scientists the teachers had chosen, but then select and investigate a new female scientist on their own or in pairs, making a unique diorama on that person. However, the investigators had spent several hours researching scientists and locating appropriate images, so they knew that the day camp students would not have time to investigate a new scientist.

The reader may want to extend the diorama project presented here to allow students to connect reading and writing skills to their investigations of women scientists. Common Core standards (Common Core State Standards Initiative, 2012) for fourth grade literacy addressed by student research are shown in **Table 5**. A checklist of what to ask students to find about the scientist would facilitate this work. Ideas for the checklist include: 1) Images: Find photographs of the scientist's face, of her working, of a building associated with her (perhaps a laboratory, office building, museum, university, home) and of the interior of the building (for the interior diorama scene); 2) Science work: Find out what science topics and concepts she worked on, what her contributions to science and society were, any awards she received, and objects associated with her work (for inclusion in the diorama scenes); 3) Personal: locate information about her personality, the challenges she faced, her education path to her science career, what she cared about most, and any interesting quotes from her.

Table 5. Common core literacy standards applied to independent student research into a woman scientist for creating a unique diorama.

Common core standards for literacy	Application of standard to diorama project
RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.	Explain where details portrayed or written on the diorama originated in text.
RI.4.3 Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.	Explain details of women scientists' lives and illustrate these as three dimensional diorama scenes.
RI.4.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.	Use book, journal article, and Internet sources to discover information about a scientist, integrating the ideas from multiple sources.
W.4.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.	Write a short summary of the work of the scientist to be glued to the diorama. Create informative labels for diorama objects and scenes.
W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic.	Investigate various websites and print sources for information about the life, work, and personal history of the scientist, taking notes that will inform the diorama.

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A Design Model for Educational Multimedia Software

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Abstract

The design and implementation of educational software call into play two well established domains: software engineering and education. Both fields attain concrete results and are capable of making predictions in the respective spheres of action. However, at the intersection, the reports about the development of computer games and other educational software reiterate similar difficulties and an embarrassing degree of empiricism. This study aims to bring a contribution, presenting a model for the conception of educational multimedia software by multidisciplinary teams. It joins three elements: Ausubel's theory of meaningful learning; the theory of multimedia from Mayer; and the study of software ergonomics. The structure proposed here emerged from a theoretical study with the concurrent development of software. Observations gathered in a small scale test confirmed the expected design issues and the support provided by the model. Limitations and possible directions of study are discussed.

Keywords

Multimedia, Educational Software Design, Pedagogic Issues

1. Introduction

The first years of school are characterized by a ludic atmosphere that welcomes students into a warm and receptive ambience, with a careful mixture of leisure activities and serious objectives. Toys and games are practically mandatory elements from kindergarten up to K-12 classes. Some of the goals of such environments are to develop a positive attitude towards the school and cultivate reading and studying habits. Gradually there is a shift of perspective, culminating in the university, where courses are labour-intense and adopt a rather strict—if not spartan—style. Nonetheless, teachers of all educational levels tend to seek strategies to lower stress and keep students engaged and motivated.

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Multimedia software can be helpful in this context for a number of reasons. These applications have native capabilities to show and interrelate textual descriptions, diagrams and photos, besides videos and sounds. All these means once combined represent a large contact surface between the previous knowledge of the student and the new information, helping to favour assimilation. The availability of images, animations and sound makes it possible to explore the presentation of material under ludic perspectives, counterbalance boredom and maintain the level of attention. In other terms, the students are presented to the same core information, although it is deliberately disguised only to change their internal disposition towards the subject. Finally, software can be designed to enhance the interaction between students and the learning materials, by means of activities that demand several inputs of different types.

The possibilities of using computers in the classroom are widely discussed in the literature, but the idiosyncrasies of educational software development are not addressed to the same extent. Using off-the-shelf products is just one facet of the introduction of technology in the classroom. Implementing such artefacts involves the design of interface and interaction which depend on a series of factors and unfold in a complex set of requirements. The project of such software should ideally be coupled to the instructional design of a discipline and not be limited to the design of a module. Aesthetic and artistic criteria also have a significant impact on the way students perceive the computer and get involved with it. Finally, the trade-off between the development cost and the utility of the product, as part of a set of comprising books, laboratories and other elements, is seldom discussed.

Several domains are interwoven in the design and construction of educational software and multimedia; three tools are considered here in order to structure the requirements and the design of such applications. The area of human-computer interaction and more particularly, the study of ergonomic interfaces helps to shape the overall design of applications and avoid mistakes that could negatively affect most users of a given audience. The Cognitive Theory of Multimedia Learning (CTML) of Richard Mayer is a landmark in the field of educational software, providing important heuristics aiming to optimize the effects of multimedia as instructional means. Finally, the Theory of Meaningful Learning (TML) of David Ausubel proposes explanations for the mechanisms behind learning and gives clues about how learning materials should be organized, so that software is integrated into a thorough instructional design. Taken together, this information can feed software engineering processes and provide references for the project and implementation of multimedia instructional programs.

This article discusses the design of multimedia software integrating these different views. An application was developed for the subject of biology, for Brazilian students with little contact with computers. Evaluations of a group of specialist and of the students are presented and discussed.

2. Organizational Issues in Educational Software Development

The project and implementation of any computer program is based on software engineering principles, which affect product quality and process efficiency (Pressman, 2009). The field covers a broad range of issues, varying from technical content like algorithmic complexity and hardware performance, to team management and psychological aspects involved in quality control (Weinberg, 1999). The development of educational software can be particularly complicated due to multitude of aspects to be considered, comprising cognitive and psychological effects as well as several technical problems like programming fast graphics or simulating physics to increase the realism.

Despite its relative youth, software engineering can be considered a mature field, being capable of coping with the construction and maintenance of all the complex informational infra-structure that surround us nowadays. To this end it has methodological tools to integrate specific expertises into the development of computer programs. The examples are abundant: medical tools, engineering programs, economics, chemistry and, of course, educational applications. However, working with multi-disciplinary teams may still be a daunting task. For instance, a typical programmer or software analyst is not used to the subtleties involved in the transmission of information during a teaching-learning interaction:

"*Instead of guessing, designers should have access to a pool of representative users after the start of the design phase. Furthermore, users often raise questions that the development team has not even dreamed of asking*" (Nielsen, 1992b).

Even if this statement is twenty years old, it remains a fresh truth in software engineering. Teachers are not acquainted with the technical barriers, nor the possibilities, that define the choice of a given set of functions or features that should be implemented in new software. Despite being well-documented in the informatics literature (Yourdon, 1989; Weinberg, 1999; Pressman, 2009), these issues are recurrent.

A minimum-team for educational software development would include a teacher, a programmer, a graphical artist and a manager, as these four persons cover the basic tasks and responsibilities associated with a project of this nature. The integration of experts in a team and the exchange of information must be constantly and actively supervised. Even small teams give rise to complex social interactions (Kirkman & Rosen, 1999). The project manager must balance different views (Weinberg, 1999).

One of the most critical aspects of software development is the initial phase of requirements elicitation (Pressman, 2009; Wiegers, 2003). Software behaviour, user expectations, hardware specifications are some of the characteristics that must be tailored to the application domain using information gathered from several sources, which include regular users, experts, technicians, investors and also standards and regulations. The boundaries separating the areas and the professionals are not very sharp (Weinberg, 1999; Flynt & Salem, 2005).

Concepts, ideas and knowledge from the domain of pedagogy enter as inputs to engineering processes. Inversely, constraints related to the computer and the resources available, may steer the project in a manner not foreseen by the teachers.

Final users and experts like teachers, psychologists and students can actively participate of the implementation, providing drawings, modifying the project of the interface, validating prototypes. **Figure 1** identifies this domain of action by calling it the "teacher space", distinguishing it from the work of programmers and analysts, called here the "software engineering space". There is a mutual influence between the areas that must be balanced throughout the implementation. For instance, a choice like presenting or not videos in the interface is directly related to instructional design expectations and needs. However, it will be up to the technicians to determine the feasibility of this requirement and, if possible, to project and create a solution. Eventually a request must be turned down on the basis of technical or resource limitations, this way making it necessary to reconsider the project in the teacher space. The inverse may also happen, opening possibilities that were not considered at the beginning. The gray gradient of the figure represents the interwoven nature of this relation between experts.

There are different ways to organize the implementation of a software project. They range from the management of small applications carried out with PSP (Personal Software Process) to projects counting hundreds of developers relying on methods as the CMMI (Capability Maturity Model Integration). Giving the intrinsic complexity of multimedia, the use of a methodology for development should not be underestimated, even in modest projects. Studying the available choices is out of the scope of this article; the interested reader could refer to Pressman (2009).

Multimedia applications share many characteristics with videogames. Both tend to contain numerous artefacts that include drawings, diagrams, sounds, music, storylines, descriptions of characters, texts and dialogues. The array of items may require specific management tools as versioning control and indexing (Flynt & Salem, 2005).

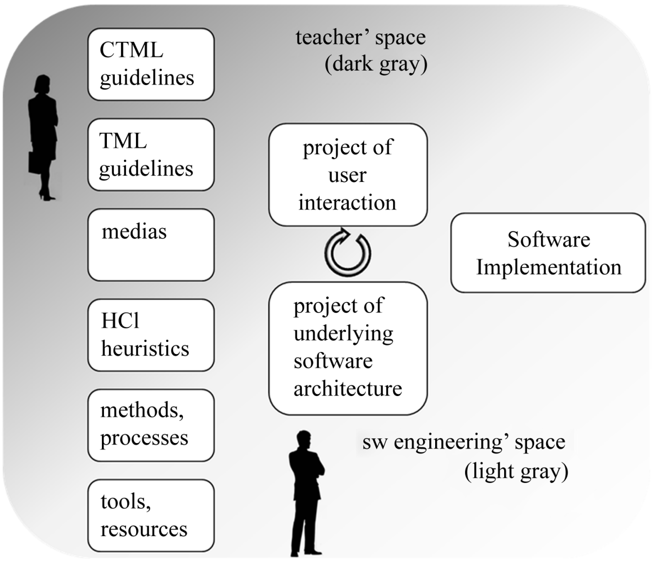

Figure 1. Educational multimedia design space.

A crucial, yet simple tool, often used in management by the videogame industry, is the Game Design Document. In its original form and purpose, it is a document making a description of the software from the user viewpoint, without much concern for the internal architecture (Bethke, 2003; Rollings & Morris, 2004). It describes artefacts as the layout of screens, sequencing of tasks and possible paths of interaction that have a clear interest in an educational setting. The document functions as a focal point for the development team, helping tasks as evaluation of possible designs, negotiation of priorities and definition of deadlines. Non-ambiguous, complete and accurate design documents avoid difficulties and problems that can permeate the project up to the final product implementation (Flynt & Salem, 2005; Pressman, 2009).

Complementary to the Game Design Document, storyboards and prototypes (Meigs, 2003; Johnson & Scheleyer, 2003) are invaluable for educational multimedia. They allow discussing the project with an eye on the finished product.

3. Interface Design and Educational Software

Human Computer Interaction (HCI) can be thought of as a subset of interaction design (Preece & Rogers, 2002). Interaction design is a field of research concerned with the interaction between humans and things like cell phones, control panels used in industries, airplanes cockpits or everyday objects.

The typical computer interface devices—keyboards, mice and touch screens—are, in a certain sense, very limited artefacts: if we observe users interacting with software, we see silent people staring at screens, making movements with their hands while their bodies rest immobile for long periods. All the richness of the tasks being executed is concealed in the cognitive interaction between the users and the elements that are presented on screen. In fact, the project of computer interfaces involves a high level of subjectivity (Nielsen, 1992a; Preece et al., 2002). As a consequence there is a rather paradoxical problem in software engineering: while the design and implementation processes are well known and reasonably controlled, the exact quality and behaviour of the final software is less certain, being highly dependent on a given context of use (Weinberg, 1999; Koscianski & Soares, 2006). Interfaces are, in this sense, blurry targets and the difficulty to forecast the success of a videogames is a good example of this (Bethke, 2003; Rollings & Morris, 2004).

The discipline of HCI studies the relationship between humans and computer interfaces from several viewpoints. For instance, the analysis of tasks offers a perspective to organize sequences of user actions, like pressing buttons and filling fields with information, in order to increase efficiency and prevent mistakes; the field of psychology gives clues on how to draw attention, avoid distractions and keep users focused; and research in physiology and cognition helps to understand how people react to stimuli and how they cope with tasks using information that is laid out on the screen. A straightforward example is to limit the branching factor and the number of items that are shown in menus. The famous work of Miller (1956) discussing short term memory is one of the firsts among a long series of research around cognitive capabilities.

Making a coherent unit out of all these pieces of information is a non-trivial task. The field of HCI has established criteria that helps guide software design and avoids most evident flaws (Nielsen, 1992a).

The international standard ISO 9241 is an important reference for interface design. It gives a series of advices concerning ergonomics, but leaves out the needs from specific domains like education. This issue has been addressed by several studies, some examples being Squirres and Preece (1999); Ardito, Buono, Costabile, Lanzilotti, & Piccinn (2009); Alsumait & Al-Osaimi (2009). The general character of the standard and its orthogonal organization make it possible to map virtually any set of requirements. **Table 1** illustrates this point with one of the studies specific to educational software.

The first two columns of **Table 1** lists the principles from ISO 9241, part 10; and the heuristics established by Nielsen (1992a) for usability of software. Both sets represent very condensed information that unfolds in more specific characteristics. For instance, in Safdari, Dargahi, Shahmoradi, & Nejad (2012) a questionnaire of 75 items was derived out of the seven ISO principles presented in the first column of the table. In the same manner, the requirement "conform to user expectations" is reworked by Alsumati and Al-Osaimi in several remarks, adapted to the universe of children education.

Besides covering all foundation of user interaction—a rich subject in itself—HCI should also accommodate instructional demands that are not part of most computer programs. Usual applications are designed to support tasks executed in a straightforward manner; examples are editing a letter, filtering information in databases, and buying products on Internet. ES, on the other hand, deals with the deep interaction that may (or should) exist between a person and material to be learnt, and objectives similar to those existent in class, such as:

Table 1. A comparison between three sets of IHC heuristics.

Principles listed in ISO 9241-10	Heuristics from Nielsen (1992a)	Heuristics from Alsumait & Al-Osaimi (2009)
Suitability for the task	Aesthetic and minimalist design	Challenge the child, evoke child mental imagery, use multimedia representations
Self-descriptiveness	Recognition rather than recall	Learning content design (adequate vocabulary, illustrate abstract concepts)
Controllability	User control and freedom	Use appropriate hardware devices (match motor effort and children skills, prevent input errors)
Conformity with user expectations	Match between the system and the real world; error prevention	Attractive screen layout, support child curiosity, assessment (provide reports to instructor)
Error tolerance	Help users recognise, diagnose, and recover from errors	- (Only lists Nilsen's heuristics)
Suitability for individualization	Flexibility and efficiency of use	- (Only lists Nilsen's heuristics)
Suitability for learning (learning the software use)	Recognition rather than recall; help and documentation; consistency and standards	Design attractive screen layout (screen uncluttered, readable)

- distribute information along of space and time according to pedagogic criteria;
- intentionally leave blanks between concepts, images and words so that links be identified during the interaction with the material or even later, during a subsequent lesson;
- ask users to solve problems, analyse their reasoning and give feedback about performance;
- entice a positive affective experience on users (Immordino-Yang & Damasio, 2011).

These ES characteristics are strongly connected to the interface organization, but they clearly go beyond ergonomics and have a complex dependency on individual cognitive differences. At this point, the software designers must call into play other conceptual references, as those discussed in this article.

A promising line of research is the development of adaptive multimedia or hypermedia systems, conceived to react to user particularities; see for example Brusilovsky & Millán (2007); De Bra & Calvi (1999). Such approaches tend to emphasize the possibility to classify and model the interactions between user, the software and knowledge; they generally leave aside the complexities of human contact and classroom dynamics. In this sense, the ES is treated in a distance-learning perspective.

4. The Cognitive Theory of Multimedia Learning

The field of computer ergonomics gives support to a critic part of design: the interface and immediate (short-term) user interaction. However, the studies in this area offer limited advice concerning the teaching-learning processes that are expected to occur with the support of computers. The interaction between students and the information on the screen involves internal cognitive mechanisms that are, in principle, out of the scope of HCI.

A reference for instructional multimedia is the Cognitive Theory of Multimedia Learning (CTML) developed by the psychologist Richard E. Mayer. Undoubtedly he is best known by the investigation of the functioning of our visual and auditory channels, but he also examined other aspects of learning. This includes the effect of different sequences of presentation on retention, the influence of working with whole-part relations, or still the way information is associated and retrieved.

Mayer exploited the ability of computers to handle different information, as a means to strengthen the contact between the learner and the instructional material. A basic idea that underlies his work is the additive effect of using more than a sensory channel:

"*Verbal and nonverbal systems are assumed to be functionally independent in that one system can be active without the other or both can be active in parallel. One important implication of this assumption is that verbal and nonverbal codes corresponding to the same object* (*e.g.*, *pictures and their names*) *can have additive effects on recall*" (Paivio, 1986).

It is worth pointing out that CTML present similarities with the learning styles proposed by Felder (1988) or Kolb (2005), see also (Sankey, Birch, & Gardiner, 2011), but it has roots in a physiological comprehension of the way individuals process information. The term "multimedia learning" (Mayer, 2001) refers to the process by which an individual builds a mental representation of contents presented concurrently by means of words and pictures. Each type of information undergoes a different processing in the brain. Handling textual data requires linguistic skills to decipher a stream of symbolic data, while visual sources like a photograph, can be perceived as a whole. There is much evidence about cognitive differences associated with each type of information processing in the brain (Gardner, 1983; O'Reagan & Noë, 2001; Banich, Milham, Atchley, Cohen, Webb, & Wszalek, 2000), that support the original observations of Paivio and the subsequent work of Mayer.

CTML is based on three assumptions: verbal and visual information are treated along of different paths in the brain; each cognitive channel has a maximum processing capacity; and learning requires an active involvement of the student. These ideas are further developed into a set of principles or effects that serve to organize the design of instructional multimedia. They are listed in **Table 2** according to a categorization given by Mayer himself.

The principles listed in **Table 2** have been extensively tested (Mayer, 2008). They have been used as means to guide the design of educational materials (Park & Hannafin, 1993; Herrington & Oliver, 2000) and to predict learning results (Mayer, 2001). In order to use CTML successfully, two points should not be overlooked.

The text of the standard 9241 and the format used by Mayer to present his theory resembles a list of items. Although didactic, this can be misleading in practice, since a strict verification against a checklist can lead to a shallow evaluation (Tergan, 1998; Squirres & Preece, 1999). A better perspective is that of a structured walk-through (Yourdon, 1989); the team can inspect the product according to individual expertises, and a set of guidelines remains as a reference or a reminder. As an example, a rule that determines the positioning of buttons on the screen can be broken in favour of a different layout to present a diagram, provided that the end result will be actually advantageous to students.

Videogame developers face similar difficulties: they must pay attention to clear ergonomic directives, like limiting the number of simultaneous options on the screen; and at the same time, the project must seek the wider goal of providing a joyful experience, an extremely subjective target.

CTML is also concerned with the fact that the project of software corresponds to a fraction of the instructional design. Every element—software, books, explanations, exercises, assignments and so on, should be framed by a pedagogic structure, adapted according to the teacher style and the class needs.

5. The Theory of Meaningful Learning

The rich variety of learning theories reflects the complexity of phenomena that take place when students engage in cognitive tasks and social interaction. Works from scientists as Piaget, Bruner or Vigotski, establish what we

Table 2. CTML principles.

Principle	Category	Description
Coherence effect	Reduction of extraneous load	The material presented to the student should avoid including information that is not part of the contents being studied.
Signalling effect		A presentation should give clues to students to guide their attention towards main points, by emphasizing or repeating information.
Redundancy effect		Narrated text should not be accompanied of written text, since this can distract students from observing pictorial information.
Spatial contiguity effect		The close placement between texts and pictures reduces the effort of students to inspect material and favours learning.
Temporal contiguity effect		The presentation of verbal and non-verbal pieces of information should occur simultaneously instead of sequentially.
Segmenting effect	Management of essential processing	The presentation of information should use separable units whenever possible, instead of fusing several concepts into complex texts and pictures.
Pre-training effect		Introductory material in the beginning of a presentation, may reduce the cognitive load associated to complex information that forms the core of the learning material.
Modality effect		When pictorial and verbal information are combined, the use of narrated (spoken) text is preferable over written text.
Multimedia effect	Fostering generative processing	Explanations with text and pictures are more efficient than those presenting information using only one of these possibilities.
Personalization effect		The presentation of material should preferably make students feel part of the narration, for example using second person instead of third person conjugation.

could call "angles of approach" to deal with the task of teaching. Each system of assertions and methods forms a coherent set that can be used as the base for instructional design of books, lessons, software.

David Ausubel was a psychologist who developed research in the field of education. His work led to hypothesis concerning the functioning of the brain on an abstract, symbolic level. This view is closely related to information processing theories and cognitive approaches (Schunk, 2012).

The theory of meaningful learning was chosen in this study for two reasons. First, there is a number of links and agreements with the work of Mayer. Both authors share the viewpoint that cognitive phenomena can be explained by mechanical or information-processing metaphors, what is highly convenient in order to think about software design. Second, both theories focus the interaction between the individual and the information. In doing so, they do not preclude, neither require, adjustments to the social context. When this is necessary, the corresponding requirements elicitation must be carried out and incorporated into the project. As an example, social networking could have an effect on the sequencing of information presented on the screen. This kind of consideration falls outside the scope of this study.

Ausubel emphasized a distinction between two types of learning processes: rote memorization; and transformation of cognitive structures. In the first type of learning, individuals record facts in an arbitrary way. Examples are studying a list of items or associations, like capitals of states. In the second case new information is also stored in the brain, but this involves a network of facts that are likely to modify pre-existent knowledge. For instance, when students learn that friction is a force, their comprehension about several situations in mechanics gains new interpretations (Clement, 1982).

Learning in a meaningful way requires pre-existent knowledge that can be related to new information by the student. This process can lead to an integrative view of various concepts, or inversely to the differentiation between them. For instance, "plant" is an umbrella for things as different as "sequoias" and "roses", while the terms "angiosperm" and "gymnosperm" can be understood as two particular types of the general concept of "plants that produce seeds".

Not surprisingly, the anchoring mechanism does not filter or ensure the quality of information and students may acquire misconceptions (Stefani & Tsaparlis, 2009). Among the causes, teachers may propagate wrong concepts, possibly inherited in turn from their own teachers (Quílez-Pardo & Solaz-Portolés, 1995); flaws in the instructional design may cause fragmented and shallow understanding (Cooper, Grove, Underwood, & Klymkowsky, 2010); students also call into play heuristics as generalisation and simplification, which may produce distortions and false conclusions (Talanquer, 2006).

The associations between concepts can take a myriad of forms and can be represented as a network of ideas (Novak & Cañas, 2006). Some possible relations are represented in **Figure 2** and labelled according to the Theory of Meaningful Learning (TML).

In subordinate learning, new ideas are connected to the cognitive structure as particular cases of a more general concept. The super-ordinate learning works in the opposite direction, by subsuming old ideas in new higher-level concepts. Finally, in combinatorial learning information get interrelated in non-hierarchical ways. In Ausubel's view, "meaning" is the result of the interaction between ideas. This way, by learning new ideas one can modify previous knowledge, up to the point of replacing and obliterating information.

If, during a lesson, students do not remember past knowledge or fail to recognize it as relevant, the quality of

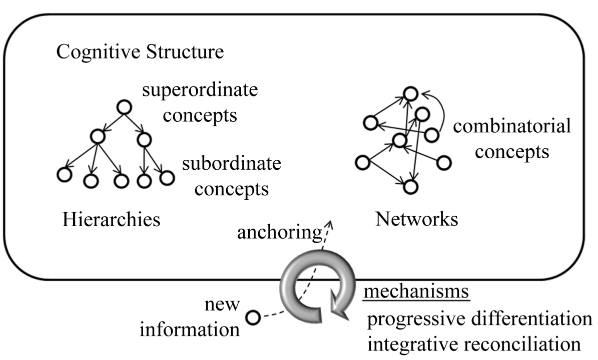

Figure 2. Overview of mechanisms from TML.

assimilation is compromised. Ausubel devised a strategy to deal with this problem, by introducing students to material that can help select and activate such memories; he called them "advance organizers". They can take forms as diverse as pictures, texts, exercises or even spoken dialogues.

An advance organizer (AO) shows only information that is likely to be known, not new facts. It is presented at the beginning of a lesson, with the purpose of making students aware of their own knowledge. As an example, the concept of "couple" or "moment of a force" can be presented in a Physics lesson with the help of the formula $\tau = \boldsymbol{dF}$, where $\boldsymbol{d}$ and $\boldsymbol{F}$ stand for the displacement and the force vector, respectively. Despite the formula being short and the mathematics uncomplicated, the abstract nature of the communication pose difficulties in class. A possible AO for this subject would be a video, showing someone struggling to remove a screw with spanners of different lengths (Koscianski, Ribeiro, & Silva, 2012).

Teachers know from experience that the design of a lesson must account for the level of knowledge of the students. However, the TML assigns a great weight to the detailed structure of such knowledge, which can explain subtle variations in tasks like comprehension of concepts and formulation of hypothesis. For instance, in the example of the moment of a force, the fact that the discussion about the formula is preceded by the presentation of a video is likely to make students more comfortable with the algebraic representation (Koscianski, Ribeiro, & Silva, 2012). If instead the formula is presented as the core of the lesson, then any examples can be perceived as a means to assimilate the mathematical notation and not as instances of application.

During the instructional design, it is possible to take advantage of the concepts of advance organizer and information anchoring even if the exact background of the students is not directly evaluated. Teachers may outline hypothetical cognitive structures that capture facts, ideas and situations that are expected to make part of the students' repertoire. This includes things from their quotidian, contents that have been taught previously and that are revealed by dialogues in class and textual assignments. This material will serve as an organizational basis to plan the approach in class, allowing the forecast of difficulties, potential sources of misunderstandings and different angles to attack a subject. It also clarifies potential connexions between concepts.

Hypothetical cognitive structures can be represented as concept maps that, in turn, can drive the creation of storyboards (Meigs, 2003; Johnson & Scheleyer, 2003). These tools can help design the different exploration paths that students may use (Ford & Chen, 2000).

6. Connecting the Tools

Taken together, the areas discussed form a thorough basis for the whole engineering processes, during the implementation of educational software.

The discipline of HCI is directly related to software development and borrows material from psychology, but is has no specific links to education. One exception is the requirement that the interface of a program be easy to learn and understand, based on the premise that any computational tool should be unobtrusive.

On the other extreme, the theory of Ausubel dives into the domain of cognition but has no particular concern about the medium employed to deliver information. It makes little distinctions between the use of books, oral explanations and other vehicles. The emphasis is placed in higher cognitive tasks like comprehension and extraction of information.

Mayer's work stands as a possible bridge between both worlds. The interface is treated using principles as contiguity and multimedia, while mechanisms associated with deeper assimilation are exemplified by principles as pre-training and segmentation. CTML, however, does not offer thorough answers about the construction of interfaces as does the HCI discipline, neither predicts learning outcomes with the same amplitude as TML.

Table 3 shows a general view of the areas and their emphasis, mapped in a diagram shown in **Figure 3**. The layered structure of the diagram also reflects a temporal approach to the project, where the top level—the interface—corresponds to the last element to be refined.

TML provide the deepest level of organization. Its principles will justify the choice and the organization of the contents. It gives criteria to select metaphors, to draw relations, create exercises and activities, and any other aspects directly connected to understanding the actual meaning of the information. The contents of texts and images are produced and evaluated according to principles defined by TML, as the availability of previous knowledge.

Although teachers may be eager to draw interfaces and present ideas about how students will operate the software, such considerations should be deferred in a first moment. The team should question how the teacher

Table 3. Overview of the model.

Tool	Focus	Time scale	Intervention
HCI	Symbol recognition, workflow, short-term memory	Immediate symbol and information recognition	Immediate interaction; easiness of interface comprehension and usage
CTML	Contents assimilation	Short/long term memory	Density of information and efficiency of communicating
TML	Deep, complex learning	Life-long learning	Design of the whole instructional material

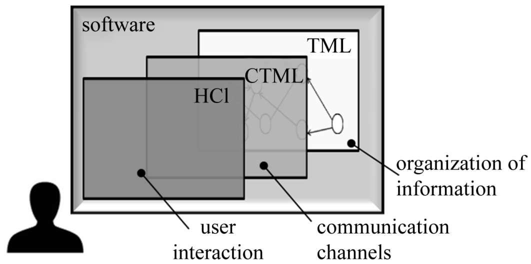

Figure 3. A layered view of the combination of the different tools for software design.

intends to explain each concept, idea or problem, and how that's done during a classical lesson using pencil and paper. It is only when clear strategies have been identified and understood by the team that the translation into software can take place. As a single example, during the discussion about a mathematical game showing a coordinate plan, the teacher casually mentioned that "cut the X axis" was the expression used in class to explain a certain property. That information immediately prompted the development team to change the scenery—which in principle was already validated—replacing a ball with scissors in order to strengthen the links between software, subject and verbal explanations used.

The main role of CTML is to organize the information vehicles that are assembled into the software, such as texts, videos, images. It helps to balance the use of different media and gives clues as how to combine them. In doing so, CTML may also help to consider unforeseen forms of presentation. For instance, not rarely teachers interpret the adjectives "visual" and "auditory" in a manner not compatible with CTML, and do not consider the possibility of spoken texts replacing written information on diagrams. The theory may hint teachers about potential approaches not used before, as creating a diagram adapted to the way a subject is analysed in class. Another benefit is to require an explicit control over the distribution of information. This means to quantify the number of pieces of information—diagrams, images, texts and vocabulary and to characterize their complexity. Experienced teachers may perform this task instinctively, but the same is far from being truth for programmers and graphic artists. During the project of a game, a certain pressure around the design of interface and game mechanics may build up and override other criteria for the distribution of contents.

The top level of the diagram in **Figure 3** does not simply echoes the decisions made in the previous steps. The interface is a two-way street that limits both the access of students to information and the access of the software to the way students think. For instance, a program can only make approximate predictions about the knowledge acquired, by means of tests and quizzes. Interpreting natural language is still an open problem and, as a consequence, the internal layers of the software must be projected to ensure that each new piece of information is correctly grasped and assembled into the cognitive structure. This leads back to the instructional design and point the need to introduce questions and additional explanations along of the interface, using redundancy to decrease the possibility of misunderstandings. The design of the interface, on itself, follows rules that seek to make the software transparent. Mouse clicks, keyboard actions, buttons as "ok" and "cancel", form a set of necessary objects for interaction but that should, as much as possible, be left at the edge of the attention of the student.

One last element should be considered: the affective dimension. More than a cosmetic feature, the design of characters, sceneries and storylines may have an actual influence on learning (Craig, Graesser, Sullins, & Gholson, 2004). There is evidence that a strict separation of emotions and cognition is artificial, both from an external, behavioural view (Storbeck & Clore, 2007; Pessoa, 2008) and from observations of physiology (Phelps, 2006). The exact mechanisms are still unclear and seem to involve interdependencies between systems of beliefs, knowledge, unconscious thoughts, feelings and other phenomena. The degree to which such relations interfere with learning and to what extent they can be controlled are subject of research, (see for instance Schunk, Pintrich, & Meece, 1996), but much remains to be explained.

For practical purposes, the sensitivity to students' preferences and cultural traits has always been acknowledged by educators. As mentioned in the introduction, it is a common practice to make adaptations in classroom, as simple as decorating it, to favour a pleasant mood. The same can be seen with the changes in style of children's textbooks and, more recently, with the use of comics and mangas in higher-education. This artistic aspect of learning materials, not only aesthetic, is rarely evoked in the literature. There is a reasonable body of research around these issues in the industry of videogames (Bethke, 2003).

A Small Scale Study

The work described in this article was originated at an attempt to circumvent the difficulties faced by K-12 Brazilian students with science contents. The specific subject was the classification of vegetables in angiosperms and gymnosperms; the primary curriculum in Brazil, as applied in classes, is quite extensive. Textbooks include a high level of detail, what comprises the identification of anatomic structures shown in photographs and diagrams, knowledge of physiology and technical names. For instance, children aged twelve may be expected to explain the difference between xylem and phloem. This emphasis on volume of data is also illustrated by the historical undervaluing of philosophy in curricula and in exams like the vestibular (university admittance test). In recent years a new trend seems to emerge, but so far textbooks remain the same.

A multimedia software was proposed as a helping tool in this context. It would give access to texts and explanations, selected images and diagrams, without the limitations found in printed material or the potential chaos of the internet. The starting idea was a sort of encyclopaedia, but during the project, the design was steered towards a game, by means of a scenario and a storyline. **Figure 4** shows one of the screens of the finished product.

The definition of the game grew out of a storyline. The plot was a conflict between good and evil, with fairies, potions and plants. Most scenes depicted a medieval castle and, although such scenery is not part of the folklore of Brazilian students, it represented nonetheless a really pleasant ambience for the public of the study. The theme was indeed selected after some input was received from children. Exercises and quizzes were included along of the software and interwoven with a background story. This ensured a continuous ambience, smoothing the rupture between "game" and "study".

In parallel to the product design, the definition of the layered approach depicted in **Figure 3** was refined. The first issue perceived in the project was the tension between different views. The teacher and the programmer had no clues about possibilities and restrictions existent in the corresponding spheres of work. This situation made

Figure 4. Screen of the implemented software (the videogame language is Portuguese).

surface again during the evaluation of the product. We will return to this issue briefly.

The initial sequencing of contents was defined by the teacher, who had twenty years of experience with the subject. Two alternatives were discussed: using the software to review the subject, or to introduce the contents for the first time to the students. In order to lower the anxiety of the teacher and also to prevent any negative outcomes, a somewhat mixed approach was selected. A quick introduction to the theme would be conducted in class, followed by the use of the computer in a subsequent lesson. This way, neither of the moments was designed to fully cover the subject; the idea that the contents should be presented repeated times was part of the overall instructional design.

The contents were laid in a sequence of units, following the scheme used by the teacher and also adopted in didactic materials as textbooks. The sequence comprised a general overview, followed by roots, stem, leaf, flower, fruit and seed. During their first walk along of the interface, the students would see these themes in this strict sequence. As the sections have been visited, they were allowed to navigate freely. This restriction helped to enforce a match between software and the lessons in class and give a sense of familiarity with the discipline.

Small texts, diagrams and photos were organized in "virtual books", present in a library of the scenery. The students followed the plot and, when presented to an exercise, could go to the library to obtain information. The choice of texts and images was based on the indications of the teacher. In this sense the software was extremely customized. Nevertheless, the final product has been used in another school with a very different public and obtained positive reviews.

In most of the screens, the texts and images were interrelated. Both the temporal and the spatial proximity between texts and images were particularly important because of the new terms that students were supposed to learn. Despite the use of storyboards, we could later spot points where this rule has not been observed. A possible explanation for this kind of mistake was the schedule pressure, since the project was part of a master thesis. Software can be compared with this respect to the preparation of other materials, as a book text. Traditional methods of peer-revision can be used to minimize this type of problem. Larger software projects, subject to financial pressures present particularities for which specific strategies have been devised (Yourdon, 1989).

Spoken narrative was never considered in the design, because the software would be operated by couples of students sharing computers in the laboratory. Nevertheless a music track was added, with a noticeable impact on the interface.

The proposed combination of viewpoints had a truly practical impact. It supported the team providing criteria to direct discussions between programmer and teacher, the realization of studies around of sketches and helping the process of decision making. The conceptual framework acted as a filter to ideas originated from personal opinions, brainstorming or simple guessing. It also gave a higher level of confidence in order to determine the sequencing of contents distributed on the software.

Once finished, the program was analysed by a group of teachers from the areas of language, biology, arts, informatics and education. The reviews were freely conducted and the reports were positive, with a few suggestions for localised improvement. In further analysis, the relative proximity between the reviewers and the researchers may have disabled negative comments. The format chosen was open-ended questions, with the objective of letting the teachers freely express their views. This decision may also have limited the depth of analysis, because the reviewers did not have any particular background on educational software. This reaffirms the cleavage between the knowledge of computer technicians and of teachers and the need to carefully administer this aspect along of software development.

7. Final Points

The project described in this article confirmed the classic predictions of software engineering with regard to planning, schedule and project administration. The strict division of responsibilities had a positive effect on the workflow, another result that is not new but that is never overemphasized among experts of other areas, not acquainted with software production. The departure had moments of hesitation, but in a matter of three weeks the project got a life of its own and the team dynamics was stabilized.

A "pre-design" phase to assess the cognitive structures of the students improves the requirements elicitation. The team relied on the previous experience of the teacher to define the contents, but did not systematically register this knowledge; the information remained controllable thanks to the small size of the project. A printed conceptual map would have been invaluable to guide the team through development, revealing potential gaps and acting as a reference to discuss different approaches to expose contents. We may hypothesize the development of CAD (computer aided design) tools for educational software, blending or linking concept maps into other diagrams and sources of information used in project and implementation.

Another important aspect is the complexity of designing the navigation graph of an educational application. Ausubel investigated the mechanisms underlying the storage and retrieval of networks of information, but did not address techniques for designing instructional material. Mayer studied instructional design, but with a focus on communication. Good lectures unfold complex subjects along of a clear path. It is our view that this old proven technique is still the more appropriate to lay the core design of hypermedia, as it seems to match the way we absorb information: piecewise, with clear hooks from one information to the immediately following it and, preferably, with a notion of purpose. In our study, the use of a storyline as a backbone proved to be a good solution to organize the software. According to this view, the free exploration of contents would happen backwards only; during software usage, students should follow a strict sequence. The question of self-guidance is evoked in the literature and needs to be clarified with respect to the approach proposed here.

Finally, balancing gamification with the "crude" objective of transmitting information is a problem that, to our knowledge, lacks a systematic approach. The teachers who reviewed the software missed the fact that the design underused multimedia possibilities. The non-blind nature of the review is hardly a complete explanation to the positive bias and observations about the appearance of the product. We could tentatively argue that the reviewers lacked enough familiarity with the medium in other to criticize it. However, this did not explain why they ignored points where additional concepts and contents could or should be included. In an ongoing study with a mathematical game, similar tendencies for loosing focus were observed with children, who tended to disregard instructions to focus on pure-game aspects. This seems to confirm the potential for the intentional manipulation of user perception mentioned at the origin of the text, although in this particular case it produces an undesirable, unexpected effect.

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Online Courses and Online Teaching Strategies in Higher Education

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Abstract

Online faculty need to engage the student. Online course work is now an integral element of mainstream higher education. Online courses often lack face-to-face interaction, peer interaction, faculty feedback and the lack of community. Engagement of the learner is essential for learning and promoting student satisfaction. There are online teaching strategies that could enhance a student's perception of engagement. This manuscript was completed by a literature review process.

Keywords

Distance Learning, Online, Engagement, Nursing Education, Teaching Strategies

1. Introduction

In 1974, Regents External Degree was the first online program that was created in 1974, and many educators believed that distance-learning model was inappropriate for nursing education (Bastable, 2014). Distance learning (DL) has been utilized since the early 1990s, especially with the development of the Internet. In 2002, 1.6 million students took courses on-line across the United States. In 2003, the number of online course students rose to 1.97 million, succeeded by 2.33 in 2004, and in 2011 it was found that a third of all the students enrolled in postsecondary education had taken an accredited online course (Lederman, 2013). Online course work is now an integral element of mainstream higher education. About 63% of schools that offer undergraduate traditional classes also offer programs online (Olmstead, 2010). Nursing schools have also adapted to this mode of course delivery. According to American Association of College of Nursing (AACN, 2008), there is a current shortage of qualified nursing faculty and the number is expected to grow within the next decade. Online programs have allowed colleges to offer courses needed; however, schools still need qualified online faculty that can engage the student that will improve retention, satisfaction, and student outcomes. The research is a literature review.

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2. Literature Review

The goal of this review was to explore distance learning and teaching strategies that could enhance a nursing students learning outcome. According to the results of a survey of more than 2500 higher education institutions in the United States, approximately one third of institutions with health profession and related higher education programs offer online courses in these disciplines (Allen & Seaman, 2008). Anxiety and isolation can be part of online learning, as well as feelings of confidence, encouragement, and mastery (Reilly, Lepak, & Killion, 2009). Online courses often lack face-to-face interaction, peer interaction, faculty feedback, and the sense of not belonging. Many institutions view online instruction as a viable method to provide quality instruction at a reduced cost (Garbett, 2011). The results of a study of Washington State Community College showed that distance learning students tended to drop out more often than their traditional students due to difficulties in language, time management, and study skills (Stephens, 2007). Students often register for online courses without the proper tools or knowledge to participate in distance learning. It is suggested throughout the literature that students have access to an online orientation to familiarize themselves with online course features and working with various document files (Schrum, Burbank, Engle, Chambers, & Glassett, 2005). The sense of belonging to an online community has been shown to be beneficial to student engagement, persistence, course satisfaction, and perhaps even perceived learning in online courses (Liu, Magiuka, Bonk, & Lee, 2007). Engagement of the learner is essential for learning and promoting well-being. A student should feel connected to the college, faculty, and other students even if they are not actually sitting in a traditional classroom. The other avenue to explore was the theory that any nursing professor can teach online. This is not the case. Most instructors new to online teaching begin with little to no training or preparation specific to this delivery mode (Fish & Wickersham, 2009). Nurse educators must be prepared to use technology in their classrooms and prepare to educate via online mode. Often it is more difficult for the instructor to organize and plan a distance-learning program, especially since many are new programs and their organizational needs are different from a traditional learning program (Stanton, 2001). Often students are able to learn in ways that traditional classrooms would not be able to provide. When course design and the learning environment are at their optimal conditions, distance learning can lead students to higher satisfaction with their learning experiences and produce solid student outcomes (Kirtman, 2009). Evidence shows that instructors need to maintain substantial involvement in online courses (Reushle & Mitchell, 2009) to engage the student.

3. Online Teaching Strategies

Educator's role is to facilitate online discussions and providing structure. Learning outcomes for the student is essential. There are online teaching strategies that could enhance a student's perception of engagement, increase retention, and satisfaction.

- Open the course at least one week prior to traditional classes starting.
- Post a brief introduction of yourself, with a current picture.
- Provide links.
- Discussions should be weekly, informal or formal.
- Use rubrics for grading online discussions and assignments.
- Provide syllabus, course schedule, and your expectations of the student.
- Online office hours.
- Provide the student with campus office hours and your email.

The above strategies is found in many different articles, however the above is also based on this educator's personal experience with the peer review process for online courses. By opening the course at least one week prior to regular classes starting, allows the student ample time to review the setup of the online course. The course needs to be complete with a course syllabus, schedule with assignment due dates, and a grading rubric. If learners have positive perceptions of their interactions with the technological tools of the learning environment, it is likely that they will also have positive perceptions of their interactions with faculty and other learners (Arbaugh & Rau, 2007). By posting a brief introduction of yourself, just like what you would state in your classroom and a picture(s) will also provide the student with a visual connection. Encourage the students to post their picture in the discussion forum. Pictures allow the student to have "face-to-face" interaction and promote the sense of community. Students should also introduce themselves and post a peer response. Include links that you will be referring to such as library, research, journals, and even videos. The book for the course can also be linked to the college bookstore, with a picture. Discussions should be weekly or chat rooms with peer posts that allow faculty feedback to promote the community and to facilitate learning. Using online office hours, posting traditional office hours, and contact information such as email, telephone number or even Skype information will enhance the student's learning perceptive. Faculty should also be complainant with American Disabilities Act (ADA) by using voice over power points to engage the hearing-impaired student.

4. Conclusion

The roles instructors play in facilitating productive online discussions can include managerial, social, pedagogical, and technical (Reushle & Mitchell, 2009). Educating our students via online format is expected in many colleges today. Educators need to take the time to develop courses that utilize the most current technology that enhances the students learning. By following teaching strategies, this will enhance the online learning environment and provide student engagement, retention, and satisfaction will increase.

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