Students' attitude change towards science when learning with a virtual world based curriculum: a case study

Atitude dos estudantes em relação à ciência muda quando aprendem com um mundo virtual baseado em currículo: um estudo de caso

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Resumo: O propósito deste estudo de caso foi examinar se o mundo virtual baseado no currículo das ciências pode mudar as atitudes dos estudantes para com as ciências e as carreiras relativas ao universo científico, e identificar desafios durante o desenvolvimento e a implantação do currículo. A "Ciência através do *Second Life*" (StSL) é um projeto inovador que busca criar um ambiente de aprendizagem envolvente para alunos do ensino médio, usando o mundo virtual do *Second Life* e outras aplicações na grande ecologia da Internet. O StSL foi desenvolvido, prototipado e implementado pela Global Kids Inc., uma empresa não governamental baseada em New York. Os dados foram coletados entre 19 estudantes calouros do ensino médio (dez mulheres e nove homens), durante um semestre, com observações em salas de aula, pré e pós-pesquisa, e entrevistas semiestruturadas. A análise dos dados revelou que vários estudantes passaram a considerar uma carreira em ciências o StSL currículo, e muitos disseram ter um melhor entendimento de como os cientistas pensam e trabalham.

Palavras-chave: mundos virtuais, atitude dos estudantes, ciência, engajamento.

Abstract: The purposes of this case study were to examine if a virtual world based science curriculum can change students' attitudes toward science and science related careers, and to identify challenges during the development and implementation of this curriculum. The Science through Second Life (StSL) curriculum is an innovative project that aims to create an engaging learning environment for high school students using the virtual world Second Life and other applications in the larger Internet ecology. The StSL was developed, prototyped, and implemented by Global Kids Inc., a non-profit organization based in New York. Data was collected from 19 freshman high school students (10 female, 9 male) during a school semester through classroom observations, pre- and post-surveys, and semi-structured interviews. Data analysis revealed that more students considered having a science related career after participating in the StSL curriculum, and many reported having a better understanding of how scientists think and work.

Keywords: virtual worlds, student attitude, science, engagement.

INTRODUCTION

A technology-related research and consulting firm, Gartner, Inc. [1], estimates that by 2011, 80% of active Internet users, including Fortune 500 enterprises, will have a presence in some form of 3-D virtual world environment. These virtual worlds are expected to have a large impact on teaching and learning in the very near future. Virtual worlds are usually 3D game-like, multi-user, graphical computer environments where users represent themselves with graphical characters called avatars. Although graphical virtual worlds became popular only in the last decade, they were welcomed by various fields including education. This is not surprising as new computer technologies have been utilized in schools for decades to increase student achievement and motivate students to learn various subjects. Science and mathematics are intimidating to many students, and are perceived as difficult. Game-like environments are known to bolster student engagement, and may have a mediating effect in changing student attitudes towards these topics.

Virtual worlds are becoming preferred educational tools in K-12 institutions because of their affordances to facilitate learning various school subjects. Among these affordances are supporting collaboration, being interactive, allowing users to create content, and multimodal representations. Learning experiences within these worlds generally focus on explorations and active experiences that both engage students and motivate them to explore new concepts. One of the projects exploring educational effectiveness of virtual worlds for science learning is "Science Through Second Life" (StSL) curriculum which is an innovative high school curriculum was prototyped by Global Kids, Inc. in New York City to educate and inspire youth about science through the incorporation of the virtual world Second Life (SL) and related online media.

The potential of learning in 3D virtual spaces uses the strength of other digital media tools and brings them together in an embodied way. Therefore, the StSL curriculum was designed to harness the strengths of each media used throughout the project and appropriate them to facilitate student learning. Once the technologies and learning processes are embodied, youth can collaborate with each other. In this way, it is different from working on a shared Google document, where there is no sense of place.

This paper presents results from a single case study which was conducted in an urban high school freshmen global science course taught by using SL virtual world in Spring 2008 semester. We will talk about the study itself, what kind of activities engaged students in learning and exploration more than some others and make suggestions to educators who plans to use virtual worlds for their K-12 instruction. Specifically, the main research questions were following:

- How did students attitudes towards science and science related careers changed when they learned science with StSL curriculum?
- What can we learn from the StSL curriculum that can be applied to design and to develop activities and curricula for other type of courses?

STUDENT ATTITUDES TOWARD SCIENCE AND VIRTUAL WORLDS

Students' attitudes are one of the key factors in learning science, and the learning process is important in improving the attitudes of students [2]. The development of positive attitudes toward science can motivate student interest in science education and science-related careers [3]. Studies show that students' attitudes toward science generally starts declining in middle school and keeps deteriorating as they advance in school [4]. This problem calls for attention to invent ways to improve students' attitudes towards science and science related careers. Studies in science and technology education show evidence that intervention focused on engagement and attitude change may have great promise in encouraging students to pursue science related careers [5].

Some studies show that computer assisted instruction (CAI) was more effective than the other methods in increasing students' interests in science lessons [6], and during the teaching process, computer assisted applications aid the consolidation of attitudes and the restructuring of knowledge by students themselves [7].

In his analysis of science education, Lemke [8] concludes that, ''Science is presented as being a difficult subject. When students fail to master it, they are encouraged to believe it is their own fault: they are just not smart enough to be scientists'' (p. 138). One of the goals of StSL project was to break this stigma.

A recent longitudinal study reported in *Science* by Tai et al. [9], indicates one outcome of students' attitudes. The researchers discovered a strong correlation between eighth grade students who expected to have a career in science and those who eventually graduated with an undergraduate degree in science. Therefore, unless we can convince students early on in their schooling that science is achievable for them, we run the risk of perpetuating the idea that science is only for a very few elite students. There has been some research done on the viability of virtual environments, similar to SL, on the teaching and learning process. Dickey [10] concluded that immersive worlds can have a significant impact on the experiential learning process. In addition, Antonacci and Modaress [11] identified the educational possibilities of using virtual environments such as SL, and some other researchers studied student attitudes towards using SL in education [12].

SL is only one of the several virtual places where today's youth's sped considerable amount of time outside of their schools. The gap between what students do at schools and their media-rich lives outside of schools might be one of the reasons for students' disengagement in schools. Although technologies are made available in schools, they are used differently (with different intentions) and to do different things than how it is students' daily lives. Recently, some projects have tried to incorporate games and virtual worlds in school curriculum to bridge this gap. While the virtual worlds gets more sophisticated and immerse in K-12 educational institutions, it's crucial to understand what kind of activities are more effective to engage students with the educational content and encourage them learning in these virtual worlds. Immersion, interaction and engagement in virtual environments are some of the main factors contributing construction of scientific mental models [13].

Creating scientifically literate citizens who can think critically, make sense of a set of complex data, and solve problems is one of the major goals for education in the 21st century [14]. Unfortunately, large numbers of students in schools are not learning the science content or developing the appreci1ation of scientific inquiry needed to become the scientifically literate workers and citizens needed by our society.

One main barrier educators have to overcome is getting students to enjoy math and science. It is considered that students' attitudes toward science affects students' motivation, interest, and achievement in science subjects, as well as on their enrollment in elective science courses and other science related behaviors [15, 16, 17]. Therefore, there have been several science projects taking advantage of digital technologies such as games and simulations. Many of these research projects done on science and technology topic were conducted in laboratory environments as opposed to actual classrooms. One of the best examples uses Multi User Virtual Environments (MUVEs) for inquiry based science education is River City project where students engage in several inquiries to solve epidemic in River City [18**].**

There is a growing body of research demonstrating that shared virtual worlds can be powerful educational tools with the potential for transforming the learning experience [19]. Trindade *et al*. [13] found that interactivity, navigation and 3D perception of 3D virtual environments may help students with high spatial aptitudes to acquire better conceptual understanding of science concepts. 3D graphical virtual worlds are multimodal environments which can attract students with different learning styles. The activities in StSL curriculum project are some of the current uses of virtual worlds which will help identify meaningful educational strategies that should be used to engage students and enhance teaching and learning.

OVERVIEW OF THE PROJECT

The StSL project was implemented from January 30th through June 16th, 2008. StSL classes took place five days a week in a ninth grade

Global Science class in a high school in Brooklyn, New York. As students learned a variety of digital literacy skills related to virtual worlds, blogging, and online media production, they were taken through a nineteen week, interdisciplinary curriculum, teaching life and physical sciences. The project aimed to build students' confidence in their ability to "do science" by leveraging the constructivist and collaborative possibilities of virtual worlds, and improve their attitudes towards science and science related careers.

More specifically, students learned science by investigating real life ecological problems through virtual world simulations that use real life data. Students made observations, gathered and analyzed data, drew conclusions, and proposed and created solutions to these problems. For instance, they were able to explore the ecological ramifications of a virtual landfill, a virtual strip mine or an oil field. They also explored and conducted experiments in the atmosphere, taking virtual samples of air at different altitudes to better understand global warming.

At the end of each marking period, assessments were conducted to evaluate students' achievement in the course. These assessments were usually digital comic book projects in which students reflected their learning by using images and text. In the beginning of the program, about three weeks, students learned the basics of using a variety of digital media tools, including SL, blogging, digital comic creation, and digital photo sharing. Lesson plans for teaching these tools were in relation to global and science issues. The later section of the program focused explicitly on science learning, covering the following subject matters:

Unit 1 – Sustainability | Unit 2 - Solid Waste | Unit 3 - Fossil Fuels |Unit 4 - Green Solutions | Unit 5 - Final Projects

Students had various instructive supports during class activities from the Global Science teacher, a student assistant, and from a virtual instructor, retained by Global Kids, in SL. The virtual instructor, located in Scotland, is also a SL expert and she helped the classroom teacher who had no previous experience with virtual environments.

One of the significant differences between the StSL curriculum and traditional science curriculums is that StSL was not fully developed and given to the teacher before the course started. On the contrary, the curriculum was developed through an iterative process throughout the semester by two expert curriculum developers. During this process, the curriculum developers communicated with the classroom teacher a few times a week via e-mail or telephone and, from time to time, they joined the classes in SL. Curriculum developers modified the activities based on the feedback they received from the teacher and their observations during the sessions.

Each student in the class was given a new wireless laptop computer with all the necessary software products installed to be used for the curricular activities. These laptops were locked in a closet in the classroom in other times. Students would take out laptops in the beginning of the class session and put back at the end. In the first semester of the year, Fall 2007, the science class had 26 students. However, because of the limited number of laptops available, students with lower overall grades were transferred to another class to continue their science course to maximize the rest of the students' interaction with digital tools while engaging in the activities.

Science Though Second Life Activities

Studies suggest that students will be engaged in a 3D virtual environment and the content being studied if the learning activities have clear objectives and few distractions such as irrelevant tasks, objects, or language [20]. For students to be engaged in the process and procedures contained within a virtual environment such as SL each task should flow seamlessly [21]. Based on these principles, the curriculum developers designed the activities and the learning environment in SL. Not all of the activities required students to be in SL; students often did research outside of SL, watched videos on the Internet, or had classroom based discussion on the given topics.

A regular class session usually started with a blog entry in response to the day's motivation question, which was projected for the students on

a screen. The motivation questions were designed to make students think about a daily course topic. For example, one of the motivation questions in the fossil fuels unit was: "53% of our electricity comes from coal. How does coal become electricity?" Students would make a prediction, search the Internet, and wrote down their conclusion on the class blog. Students then took approximately five minutes to create their blog entries, after which the teacher invited them to share their answers with the class and provoked them to think further about the questions. This was a successful way to make students think about a topic and share their ideas with others. The more these questions were connected to students' daily lives, the more likely that they had answers to these questions and the more these questions helped them with the understanding of the topic. After students completed the motivation question activity, they proceeded to the main activity. Most of the main activities in the StSL curriculum were inquiry-oriented and students usually worked on them in groups in SL.

Design of the StSL curriculum was based on the results of previous studies which indicate that students are more likely to get engaged with academic work that involves them in a process of meaningful inquiries to solve problems that extend beyond the classrooms [22]. Every unit had several activities that engaged students in inquiries in the virtual world to solve real life problems. Design of inquiry processes also provided students with enough control and emotional involvement to foster their engagement [23] with scientific activities throughout the course.

METHODOLOGY, PARTICIPANTS AND DATA ANALYSIS

Data was collected from 19 students (10 female, 9 male) in a freshmen science class in a public high school in NYC during the Spring 2008 semester through classroom observations, pre-and post surveys, and semi-structured interviews. Classroom observations were made twice a week to capture student interactions with their classmates, their teacher, and with their computers during the activities. These observations helped with understanding of classroom dynamics when technology utilized in a science course. Semi-structured interviews were also conducted to learn students' reactions about using digital tools, especially SL, for the course activities. These interviews were usually 5 minute long talks with students at the end of the classes. We also conducted a focus group interview with 10 students in the 2nd month of the semester. Pre-and post surveys were administered to learn about students' attitudes towards using technology in the classroom (i.e. *"I think computers help with my learning in school"*, "*Comic Life projects helped me to revise my knowledge of science.*", "*I enjoyed being scientists for science activities in Second Life.*") and the difficulties they had throughout the semester ("*I have lots of difficulty with Second Life interface.*", "*I got frustrated very often when we did science activities in Second Life.*"), as well as change in their attitudes towards science and science related careers (i.e. "*I think being a scientist would be exciting.*", "*I enjoy studying science.*"). These surveys consisted of 5-point Likert scale questions and open ended questions. Some questions were only pre-survey or post-survey specific. Another survey gathered information about students' scientific learning outcomes from the StSL curriculum. These were mostly open-ended questions (i.e. "*What have you learned this semester about what scientists DO?*").

We analyzed the survey data using the quantitative data analysis software SPSS 14.0. Qualitative data (open ended questions) were analyzed with Nvivo 8, using inductive codes.

FINDINGS

Although students had not used computers as part of their classroom instruction previously, they gladly welcomed laptop computers into their science class instead of doing lab sessions. In fact, StSL was the first curriculum required them to use computers as an integral part of the instruction. Students equated the hands on experience of science lab sessions to working with computers. Related to this finding, the pre-survey revealed that 16 out of 18 students would like to use computers in their science classes rather than learning from a science text book, this number was maintained

in the post survey. In a semi-structured interview, one of the students stated that he became more focused on science activities just because he was working on a laptop. We expected the laptop use would create temporary engagement in the beginning of the semester due to novelty, and decrease through the end of the semester. However, it did not happen. Students loved working with their laptops throughout the course, and never complained about putting out the laptops for use and put them away after the class.

Embodied cognitive support in SL turned out to be an engaging factor of the curriculum. This resulted in increased interest in learning and doing science. In the post survey, 72.2% of the students reported that their interest in science became greater during the spring semester. The rest said their interest stayed at the same level, but they had more fun this semester and they felt they learned more than they did the previous semester. Moreover, the combination of immersive aspect with the avatar-based feature of SL fostered students' projection their real identities into the virtual environment. While talking about their inquiry-based science experiences in SL, students talked as if they were in Naples or in the mines and used words like "*I was in…*", "*I found…*" instead of "*my avatar.*" Below is one of the female students' reaction to learning with the curriculum:

> *"I did not like science before I had this course. I wish I could have Second Life in each class. This is the most amazing thing that I've experienced in high school so far."*

Students engaged in several collaborative activities, oftentimes assuming the role of scientists. They shared ideas to complete inquiries in and out of SL. For example, in the Solid Waste unit, students assumed the role of being scientists and conducted research in the virtual Naples, which was built in Teen SL (TSL) for the unit. Students investigated what percentage of the garbage is renewable in the virtual Naples, watched videos related to the solid waste problem, and came up with solutions for the problem of real Naples. Virtual worlds enable the learner to become a creator and to have control over the elements of the virtual world. This consequently enables the learner to take control over creation of her/his own knowledge. Students' sense of control over their actions in the virtual world proved to be very motivating aspect when students learn.

Attendance and Motivation to Spend Time on Task out of the Class

When we talk about motivation and engagement, students' willingness to attend classes and spending time on completing course activities outside of classes are good indicators. Students participating in StSL project often voluntarily stayed afterschool to work on their projects, and spent time on planning for their SL activities. A good example is students' SL houses. In the Sustainability unit, the main SL project was to learn how to make more sustainable houses. In order to do so, students had to collect information from their real homes (such as electricity, food consumption etc.) and simulate their real houses by putting these numbers in their SL houses. They learned how to make their SL houses more sustainable throughout the unit by changing variables based on consumption and discuss about their implications. Students emphasized how surprised they were about their consumption and how they talked to their parents about what they learned about sustainability. Moreover, students' having virtual houses in SL created a sense of ownership and a sense of place for them. Students made their SL houses not only sustainable but also more sophisticated by adding extra floors or furniture. One of the female students surprisingly reported that she dreamed her SL house. Giving students the ownership of their houses created a sense of place inside the virtual world, and this sense of place brought increased sense of engagement throughout the unit. Another affordance of virtual worlds is that a student does not have to be physically in a classroom to participate in in-world activities. One student, who was suspended from school for 3 days due to behavioral issues, logged in to SL from his home during the class time to work with his classmates. This student woke up each day by 8:30am to attend his class virtually, which was only possible due to the use of SL. He chose to wake up early and met with his classmates in SL to complete this day's in-world

activity although he wouldn't be at school with his friends. These are only few examples of how students have been engaged in course activities which will prepare them to be critical thinkers and scientifically literate citizens in today's digital world which is full of information and computing technologies.

Students' self-efficacy and self-confidence in their abilities to do science-related work increased after participating in the StSL curriculum. The curriculum activities showed students that every student could be a scientist and this resulted in increased self-confidence. One of the female students commented on her blog *"…One thing I learned about science in Second Life is that science is really not that hard. I always thought, "I can't do this," but now I have learned so much. I learned about sustainability and how I can help to make our earth better. I never knew I was this smart…."* Compared to the traditional science curriculum, the number of students reporting being overwhelmed by science class fell by 50%. Furthermore, 15 of the students reported feeling more comfortable answering questions about global science topics.

One of the advantages of virtual worlds is that they offer various learning opportunities to students. It is crucial to address students' curiosity if we want to engage them in learning activities. While students were learning science in StSL, they could choose to put more emphasis on whatever they were interested in. Although there was a structure, within that students had a lot of freedom. If they were interested, they would build more in SL, they would write more in their blogs as response to motivation questions or as feedback, they could build in sky instead of on ground in SL, they would decide how their Comic Life page would look within the objectives. This kind of freedom provided youth with opportunities to explore their own interests within the structures curriculum developers put in place**.** Although this freedom engaged male students more, and females students were especially confused in the beginning of the semester as traditional curriculum would tell them exactly what to do instead of tapping their imagination. Nevertheless, at the end of the semester, flexibility of the curriculum proved to be a great way to give students opportunities to express themselves. For example, one of the students was fascinated by SL's building tools and had interest in 3D computer modeling, so he chose to build a hybrid car for his final project. Below what he says about the project:

> *"IT WAS REALLY FUN!!!! I enjoyed building a solar/ hybrid car for my project and I enjoyed making a billboard. I would recommend this style of learning for any subject because it keeps us (students) pushing because we are using a game for learning."*

Another male student was interested in acting. When he was introduced to a world where he can actually practice acting through role playing, he enjoyed role playing a scientist or a researcher for the activities. He pointed out role play activities were very educational for him and he wished he would do such activities in other classes. One of the female students was interested in writing and she used narratives to tell stories about her SL avatar's "*adventures*" for her Comic Life projects.

The fact that an average user can build and design in SL was an engaging feature. However, this open-endedness sometimes distracted students from actual learning goals. While students were building sustainable houses, they engaged in customizing them and making the houses into something they liked. Being able to customize was found to be one of the most enjoyable features in a virtual environment [24]. Figure 1. shows a house whose second floor and colorful walls were designed by students to make their SL houses more customized. Every student talked about excitement about they could build their SL houses, so it was clearly a motivational aspect of SL for them. However, the teacher should determine how much control s/he should give students during the science activities so that students would be engaged but not get distracted from the actual scientific goals. One solution to this might be to give more hours to build and play in SL in afterschool programs and restrict students to engage in only science related activities during the class time. Below is a student's quote about their houses**.**

> *"…In second life we got to design our own home... some questions I still have about doing*

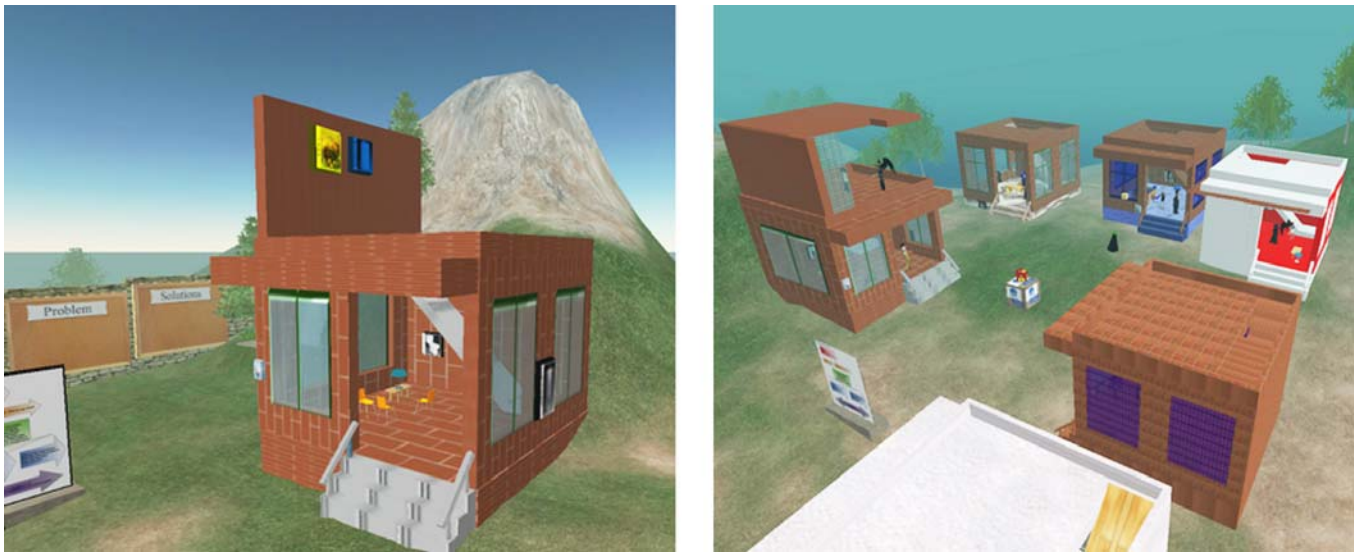

Figure 1. Student houses during the Sustainability unit.

so is how to edit multiple textures and make some of my own. I like the paint/textures we used because it reminds me of my room."

SL enabled students to "*be*" in multiple digital spaces, although physically they remained in the classroom. TSL, for students between age 13 and 18, was used for the project, so students were restricted to visiting places in TSL. Although this restriction limited the possible places they could visit and learn, this resulted in them spending most of the time at their project's sites for scientific activities. Each unit had its own unique environment which was set up by curriculum developers prior to the beginning of a unit. In a way, there was an installation environment per project.

While learning with StSL, students conducted scientific inquiries in groups in SL and played the role of a scientist (such as observer, recorder, and analyst) through their avatars. The hypothesis was that if students identify themselves with their avatars, they can start seeing the possibility of being scientists and understand how scientists think and work. All students said that having an avatar was lots of fun in SL, and all but 2 said that having avatars helped their science learning in this semester. Most of the activities in SL, especially the ones that required students to do inquiries, were group activities. In the post-survey, 11 students said that they felt more comfortable working with others to get something done using digital media compared before their experiences in StSL.

At the end of the semester, one of the things students realized was that they not only could meet with people from all over the world in SL, but they could also be introduced to other cultures and other counties in this virtual environment. For example, in the unit on Solid Waste, students did scientific explorations in Naples, which was virtually mimicked in SL, and throughout the semester many students had a chance to chat with teens from other countries in TSL.

SL was selected as the most influential media in students' science learning in StSL. Among the ways students thought SL helped them learn were that they were kept focused and never got bored, they met with other people in SL, they did many things that couldn't be done in their classroom, and they learned and experienced more.

Comic Life projects proved to be a very strong way to reflect what students learned and gave them freedom to express themselves with their work. These activities increased student confidence in using computers both for structured curricular activities and for self-initiated ones. Using comics to do their science projects allowed students to not only produce their projects in a different way than they would in a traditional science classroom, but it also allowed them to

create narratives by importing stories and pictures from SL environments and combine these with scientific knowledge in a creative way. Some students created even more comics than they were required to throughout the semester. They created comics by producing the narratives, using their own pictures taken with the built-in laptop cameras, as well as downloading pictures from the Internet and using snapshots from SL. They frequently used their avatars as narrators in their comics. Therefore, Comic Life projects helped students to use their creativity, gave them tools for text production, and made the project creation process more engaging to students. This is also supported by the findings of Kimber and Wyatt-Smith [25] who argue that when students participate in design they become more engaged than other students in similar studies.

All students reported that they enjoyed having a customizable avatar in SL. As soon as they learned how to customize their avatars, they made changes to them. Females changed the appearance of their avatars more than males did. By analyzing the snapshots in students' laptops, we found that female students changed their avatars' appearance 4.5 times on average during the semester compared to 3.8 for male students. While female students mostly changed their avatar's hair color, clothing and skin color, male students used wings, non-human avatars like cartoon characters (e.g. Sonic the Hedgehog) or robots. All students said they enjoyed customizing their avatars. This is also consistent with recent research on the effect of avatar customization on user engagement [26]. Moreover, when students took screenshots in SL, the majority of them included their avatars. Female students took significantly more snapshots (μ =31.1) with their avatar in the picture than male students did, which was 17.4 on average ($t = 2.957$, $p<0.05$). It can be argued that since female students identified with their avatars they took snapshots as they would take pictures in real life.

Student attitudes towards science

Analysis of the collected data revealed that more students considered having a science, technology, engineering and mathematics (STEM) related career after participating in the StSL curriculum. Furthermore, many students reported having a better understanding of how scientists think and work as evidenced by student surveys. A major component of the curriculum was collaborative scientific activities conducted in the Second Life environment. This study shows that these activities supported student understanding of how scientific investigations are conducted. The activities also increased students' positive attitudes towards science and STEM related careers.

Further analysis revealed that students' interest in studying science increased with the StSL curriculum. In the post-survey, 14 of the students reported that their interest in science became greater during the spring semester. The rest said their interest stayed at the same level, but they had more fun this semester and they felt they learned more than they did in the previous semester. The real life connections and scientific role-playing were helpful in changing students' assumptions about classroom science being useless outside of school. For example, after the intervention, 15 students reported a much better understanding of how scientists think and work through problems. Students attributed this change to the role-playing activities possible in Second Life.

When asked about their reactions to the StSL curriculum, all students expressed positive attitudes. Moreover, students wanted to use more of this type of instruction, especially in other difficult subjects, such as mathematics. This indicates that curricula based on a virtual world might make difficult classes more enjoyable and less intimidating for students.

Grades and Attendance

Grades and attendance were other measures that indicated engagement and attitude changes towards science. Overall, no significant difference was found between the students' grades in the Fall semester and the Spring semester. In the Fall semester, students learned with the traditional teacher-designed science curriculum. In the Spring, students learned with the StSL curriculum. The fact that no significant difference was found in student grades and attendance between these two semesters provides evidence that the StSL

curriculum is as effective as traditional, teacher-designed science curricula on these two measures.

There were other areas, however, where the StSL curriculum proved to be more effective than traditional curriculum. For example, low achieving students did academically significantly better with the StSL curriculum. More specifically, their grades increased 5.6 points on average in the spring semester. The curriculum seemed to motivate these students, keeping them focused throughout the semester. There are a few explanations for the reason why all of the students' grades did not increase. One explanation is the number of homework assignments. Although the final projects were engaging and provided students a way to reflect on what they learned, the number of homework assignments was much lower than in the previous semester. Grades might have been affected by the smaller number of homework assignments. If a student could not complete one or two homework assignments, this dramatically affected his or her grade. In a future research, we might learn more about the effect of assignments by controlling the number of homework assignments given to the students.

In terms of attendance, female students' attendance rates dropped while male students' attendance rates increased. These numbers were not significant and there was no evidence that the StSL curriculum influenced students' absence. Moreover, the teacher noted this being a common pattern in the Spring semesters. Lateness, on the other hand, improved significantly in the Spring semester. During the interviews, many students pointed out the necessity of being on time to the classes. When students were late, they felt that they fell behind in the StSL activities. This provides some preliminary evidence that virtual world activities may promote engagement and reduce tardiness.

Students' Digital Literacy Skills

The power of other digital media tools is not lost by using 3D virtual worlds. On the contrary, other digital media can be incorporated in these 3D spaces and can be used alongside them. This type of learning environment gives students many opportunities, such as communicating with others, being responsible for what they do, encouraging them to be creative citizens, or giving students opportunities to project or construct their identities through their productions and explorations in 3D multi-user virtual worlds. These are some of the opportunities that enable users' movement across digital geographies.

As noted earlier, while learning with the StSL curriculum, students not only worked in SL, but conducted other science-related activities using number of software products and Web 2.0 tools. For example, students experimented with Comic Life and Google Earth, and other social media, such as blogs and Flickr. These activities were designed to improve students' digital literacy skills. Analysis of blog entries revealed that students made an average of 47 blog entries during the semester. On average, students took 35 snapshots in SL and uploaded 10 of those snapshots on the project Flickr account throughout the semester to share with others.

One digital literacy skill that was emphasized and related to the science curriculum was the notion of reliable information. Students learned that not all information on the Internet is reliable, and that a good scientist uses multiple sources to ensure accuracy. Students used different websites to compare the information they found. For example, one of the male students did 64 individual searches on 4 different search engines while he was working on his final project. Throughout the curriculum, students have learned how to find out if the information is reliable or not with different activities. In the Solid Waste unit, students compared the news about the Naples on various websites on the Internet and on the information provided in virtual Naples in Second Life, and decided what to believe. Below is a blog entry done recently by one of the students in Global Science class.

> *"…I am using the evidence i got from multiple web sites to put together my project. not only did i use one web site to get my information i used different ones to verify the credibility of the information. from the information instead of using cars you can use alternative fuel or public transportation."*

Students reported being frustrated when experiencing "lag" (reduced frame rates) in SL

and when they have difficulty with building tasks in SL. Although building objects in SL is a difficult task, even for adults, it constitutes a constructive challenge for students. It engages them in a process with tangible (although virtual) results, a process many students enjoyed.

MAJOR CHALLENGES/LESSONS LEARNED

There have been some challenges students, instructor and the curriculum developers faced during the development and implementation of the curriculum. These played a considerable negative role in changing students' attitudes towards science and their engagement in science activities. Below are the some of these challenges.

Time: Limited class time was a challenge for all participants. In 40 minutes, students needed to turn on their computers, complete their blog entries, and get prepared for the actual activity, listen to their teachers for the instructors, work on the activity, turn off the computers and get done for that day. 40 minute class time was not enough to complete all planned activities. The long term activities need to be divided into meaningful pieces so that students can continue from wherever the left in the previous class. Both the teachers and the students said that students did not have enough time to practice their newly learned skills and to work on their science projects. Lack of time often frustrated students and affected their attitudes towards the science class.

Gender Differences: Female students reported having more difficulty getting used to the fast-paced learning activities. At times the female students expressed frustration when they could not finish a given task. During interviews, some female students said they were used to lectures and copying notes from the board—a more structured activity. The StSL curriculum, in contrast, presented a number of unstructured learning activities. This caused many female students to report difficulty using SL as a learning environment as they sometimes could not figure out what to do. Despite the fact that online help was available, many students said they needed more teacher/assistant guidance in the class to help them with their projects.

Students' Literacy Skills: Students low literacy skills were recognized in the first unit of the curriculum, and several activities reviewed by the developers to make them more student-friendly. For example, developers used check boxes or charts to give directions how to complete activities instead of a paragraph of description. Also, they used more diagrams in Second Life then the pure text.

Students' Second Life Skills: In the beginning of the semester students learned various Second Life skills including how to control their avatars to communicate with each other and building. However, again, because of the time limit, they didn't get to practice their skills very much. Especially, building skills proved to be very important for the science curriculum.

Hardware & Software: Students used laptop computers with wireless internet connection. This caused huge lag issues time to time especially when all the students needed to be in Second Life. Since students usually work in groups, it should be flexible enough so that one or two person can finish the activity in Second Life while others have different tasks on the same activity.

Scalability: The curriculum designers had to consider every detail in terms of scalability so that if other schools want to use this curriculum, they should be able to get all the materials and should be able to design the same virtual environment in a small enough sim in Second Life.

Adaptability of the Curriculum: The flexibility of the StSL curriculum proved to be critical to its success. The classroom teacher was able to tailor activities to meet her students' needs. Her understanding of her students' cognitive potential, developmental level, and individual learning styles, not to mention her technological savvy, facilitated this process. These findings emphasize the importance of curricular activities that offer alternatives for advanced students as well as low-performing students. Fortunately, the StSL curriculum consists of a number of flexible activities that can be simplified or expanded as needed. The fact that these activities took place in the virtual world did not affect the teacher's ability to individualize the activities. This flexibility was due, in part, to the open-endedness of the SL

world. It proved useful in engaging students in the science projects. It also cultivated their creativity to work on projects and provided them with tools to express their interests and identities.

Design of virtual environment and interactivity: One of the challenges of curriculum development for SL is that it's a user created virtual world. Therefore, if the designer wants to design an activity for students to interact with objects, they need to design and implement this interactivity in SL. This might be a big challenge if there is not much time for the curriculum development.

Distraction: While the StSL curriculum provided students with various learning tools, it also proved to be distracting at times. For example, during the first unit, students were asked to make their SL houses more sustainable. Instead, two of the members of a group turned their basic house into a triplex one and decorated it with fancy furniture. Although that showed that they were creative and the activity got them involved, they were not focusing on the scientific part of the activity.

Some students were very interested in improving their SL skills such as building and/or customizing their avatars. These interests distracted them from the academic aspects of various activities. One solution to this problem might be to provide students with lab hours so that they can spend time working in SL outside of class time.

DISCUSSION

The length of this case study was relatively short (only one semester), and it was a single case study. To accurately assess the engaging effects of the curriculum, more studies are needed, ideally with different demographics, and multiple cases. One needs to be cautious that students' engagement can be a result of the novelty of having use of the game like virtual world and several digital tools for the first time in a class. The attitudes may change if students are to use this kind of curriculum for several classes. Nevertheless, students' increased understanding of scientists' work and positive change of attitudes hold promise.

One of the theories which emerged to be an important part of learning in/with virtual environments is situated learning. Situated learning is learning that takes place in the same context in which it is applied. Lave and Wenger [27] argue that learning should not be viewed as simply the transmission of abstract and decontextualized knowledge from one individual to another, but a social process whereby knowledge is co-constructed; they suggest that such learning is situated in a specific context and embedded within a particular social and physical environment. Virtual worlds and games seemed to provide the ideal vehicle for providing people with such 'lived experiences' of radically different models of education for several reasons. They allow users to do things which it would be difficult, impossible, or dangerous to do in the physical world such as driving a car in very high speed and crashing it into a wall so see how force effect the car. They also allow people to test boundaries and encourage experimentation.

Within online communities, students can employ alternate personas, or "avatars," to represent themselves. This factor may have had a great importance in increasing students' motivation and attitudes towards science in the StSL curriculum. However, we did not specifically investigate role of using avatars in attitude change. Based on previous studies, avatars may have an importance for the development and exploration of real selves [28, 29], and may provide educators with a concrete representation of the abstractions of how students "see themselves" or want to protect themselves in these virtual environment [30]. Therefore, future studies should investigate role of avatars more closely for student learning and attitude change in virtual worlds.

CONCLUSION

The StSL project was challenging as well as engaging to all students. Especially, female students needed more time to learn 3D virtual environments mostly because they are as familiar with that type of environments as male students are. In spite of challenges, students became more interested in doing science, gained awareness of sustainability and environmental issues, became active learners of Global Science in virtu-

al world Second Life, and through role playing in group work they gained insight about how scientists work and thinks. Moreover, thanks to variety of digital technologies students used for classroom activities throughout the semester, they not only became more comfortable using technology in the classroom, but also they gain confidence to communicate with others in an online environment and became more aware of the implications of online shared environments.

Widespread use of technologies, mobile phones, games, virtual worlds, fosters a 24x7 learning culture. This new culture is learner centered in which trials and errors are encouraged, creativity is cheered. This new culture is where students are self-motivated to learn. Virtual worlds and games are becoming common tools in schools to encourage student engagement and attitude change. Projects like StSL can shed some light on the question of effectiveness of these tools on student learning. Student comments about the StSL experience were positive overall. Some of the common statements included "*I learned a lot*," "*I had a lot of fun*," and "*I'm a lot more interested in science now.*" Based on these results, it appears that students have discovered an appreciation for science through the hands-on experiences provided by the virtual world of SL.

To summarize, the StSL curriculum affected students' attitudes towards science and STEM related careers positively. It also provided students with digital tools and skills that helped build their confidence to pursue scientific and technological endeavors. The curriculum increased students' digital literacy skills in specific areas such as collective intelligence, and provided them with an immersive learning environment where they could communicate with their peers and instructors in several ways. Students also participated in various scientific activities in SL as critical thinkers, collaborative workers, and producers of their own knowledge. In conclusion, if virtual worlds like SL are used effectively they can be very powerful to engage students in the process of learning by providing rich, immersive environments and prove that learning can be fun.

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