A University-Based Summer Camp to Promote Construction Technology Career for High School Students

Armando Carrasquillo, Nipesh Pradhananga and Mario Eraso
Florida International University
Miami, Florida

This paper reports on high school students' deep learning of fundamental concepts in programming during a pilot summer camp organized to promote construction-related careers, especially construction technology careers, to high school students. The camp introduced concepts from programming, virtual reality, and construction disciplines to students who had little to no experience in these fields. The two-week long program utilized a project-based learning approach to increase relevance and deep learning, in addition to exposing students to learning concepts using hands-on experiences. Completion of a project was the focus of the program, and required the students to design and construct a building in a virtual environment using a programming language. To construct this building as specified in the project requirements, the students had to learn programming, use proficiently a virtual reality software, utilize their spatial visualization prior knowledge, and collaborate with each other. The objective of the program was to entice a new generation of tech-savvy students towards construction, which will eventually expedite technological adaptations in the construction industry. The challenges, findings and recommendations from the program are discussed in this paper.

Keywords: Interdisciplinary Education, Programming, Construction, Project-Based Learning, Virtual Reality, Spatial Visualization

INTRODUCTION

School system: Problem solving

The current U.S. school system uses a model in which many of its courses and subjects exist in silos, resulting in minimal interdisciplinary connections made. The content for courses such as physics, chemistry, and biology is presented usually in an isolated manner that emphasizes the specific field of study. Students who then pursue further studies in these fields usually maximize their effectiveness in a single area of learning. However, the National Institute of Building Sciences has done research that shows that some of the most resource-efficient and environmentally sustainable buildings are designed with integrated design (Vassigh, 2016). Integrated design is a type of interdisciplinary collaboration between architects, engineers, and construction professionals in which they collaborate on a project that combines the knowledge of these fields (Vassigh, 2016). The combined knowledge of these fields increases the overall performance of the project that is constructed (Vassigh, 2016). An interdisciplinary approach might be what is needed to produce beginner programmers that are prepared to continue in their studies in science, technology, engineering, and mathematics (STEM) fields. Students entering entry level programming courses tend to have a very hard time understanding the concepts due to lack of prior exposure and relevant applications. (Adu-Manusarpong et al, 2013). This difficulty with the basic concepts of programming leads to a high dropout rate (Adu-Manusarpong et al, 2013). There could be a potential remedy for high dropout rates in entry level programming courses. Having a course that takes an interdisciplinary and project-based learning approach to programming could potentially aid in this situation.

Combining the knowledge of different concepts from fields such as construction and computer science, and incorporating virtual reality (VR), high school students were provided a nurturing environment for students to learn. This interdisciplinary program could also help students from the field of construction to be better prepared for entry level programming courses. Through project-based learning, these students would be introduced to a project that they must complete by the end of the program. In order to complete the project, they must learn concepts, which would be introduced in class, and then reinforced by in class activities. These activities would help them practice the concepts and would aid the students in their preparation for the final project. Although these activities would be focused on building design, they would also have 3D visualization and programming components tied to them. By taking an interdisciplinary approach to the project, combining concepts from construction, computer science, and VR, the students would be able to produce elegant solutions for the final project (Figure 1). This interdisciplinary approach also could attract tech savvy students to the field of construction technology.

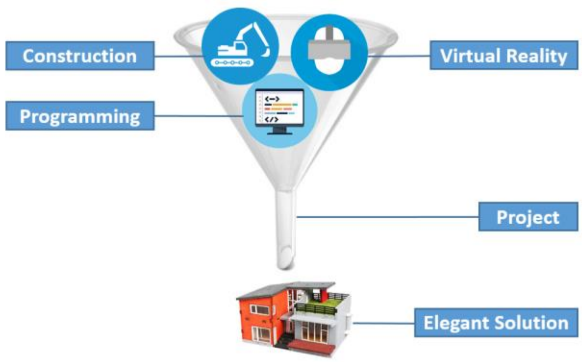

Fig. 1. Overview of the fields that are being used in this Project Based Curriculum

Project-Based Learning

The class was structured with the first week teaching the basics of programming and Unity. Unity is a game development engine that can be used to create interactive environments that can work with VR goggles like Oculus, or on a computer screen. These tools would be crucial for the student's success in the class project which they would have to complete by the end of the course. In order to complete the project, they would have to learn concepts from Construction, Computer Science, and 3D visualization. As concepts were introduced, the students were given an activity that requires various tasks to complete. The students then would prove that they understand the concepts by completing an in class activity. This educational strategy is known as Project Based Learning (Kolmos, 2009). A great benefit from this educational strategy, is that the students are learning concepts in order to complete a project. They are motivated to take part in in class activities to learn these concepts. This motivation is a key aspect of this programs educational structure, and a great benefit as well (Blumenfeld et al, 1991). With Project based learning, the students would work to complete a project of some kind. During their work, they would collaborate ideas, and concepts which would help them refine the knowledge that they have acquired. This collaboration created a small social network where the students shared thoughts and ideas. This collaboration was fueled by the goal of completing the final project. The social network created informal peer to peer interactions that potentially increased the student's retention and deep learning of the concepts (Brewe et al, 2009). By each student understanding concepts to different degrees, the moment of collaboration would be mutually beneficial for all those that participate. The daily activities were there in order to make them prepared to face the final project. Which the students also collaborated in order to complete tem. Through the daily activities and tasks, students would be able to learn the necessary information in parts and be able to apply the new concepts the same day. These in class activities have been shown to be preferred by students because of its hands on approach (Adu-Manusarpong et al, 2013). The following day the concepts would be built upon which would increase their general proficiency.

Computer Programming

Programming is a skill that has become more and more useful in society today since it has been integrated into many different fields of study. Programming can be applied to fields such as construction. In construction, programming can be used to help optimize resources and automate repetitive manual works saving cost, time and enhancing safety. Students in high school and college would benefit from learning to master this skill. Programming isn't a skill that can be acquired easily. Programing courses in Computer Science (CS) and Information Technology (IT) are viewed as being difficult, and have high dropout rates (Adu-Manusarpong et al, 2013). This view of programming often times drives students away from even attempting to take these courses because they display a low level of self-efficacy. Self-efficacy is a person’s belief that they could or couldn’t do a specific task (Bandura, 1993). By having low self-efficacy, the person would then provide less cognitive effort. With lower cognitive effort, performance in the task is affected (Bandura, 1993). Even though the barrier to entry might be more challenging than other skills, programming allows the user to be able to utilize computers to their full potential. With programming students would be able to accomplish their goals more efficiently.

Virtual Reality

The National Academy of Engineers has identified virtual reality as one of the potential grand challenges of the 21st century (Askin, 2008). Virtual reality (VR) is a computer simulated environment rendered in 3D. There are different media to display VR, but for the purpose of this program, head mounted Oculus VR headsets were used. Being a unique tool, VR has the potential to provide benefits in the classroom. The main benefit of VR is that it allows the viewer to get a better understanding of the subject matter by seeing it. These visuals could be applied to a variety of things, from showing how a building would look before it is built, to how large a blue whale is in comparison to a human being. In the field of Psychology, virtual reality is used to help patients dealing with PTSD by creating an environment tailored to exposure therapy (Miller et al, 2014). In the field of Construction, VR can be used to help architects better visualize building plans and show these designs to others that have trouble visualizing the building from the blueprints. A very beneficial aspect of VR is that it can provide students with motivation to explore creative ideas. (Lau, 2015)

With virtual reality, students are also able to see visual representations of concepts or objects in a 3D space that might be difficult to visualize. For example, the concept of how a loop works can be represented in a virtual space by placing bricks in a loop to construct a wall. Students can also see concepts that are more challenging to understand such as arrays with virtual constructs that they can see. Virtual Reality has the potential to provide students with an experience of them creating objects of any size that is only limited by their imagination.

EDUCATIONAL FRAMEWORK

PILOT STUDY

Schedule	Curriculum
Week 1: Day 1	Basic Syntax in C#: Intro to Unity activity
Week 1: Day 2	Data Types, and Objects: Unity Objects activity
Week 1: Day 3	If statements: Maze activity
Week 1: Day 4	Loops: Brick Wall activity
Week 1: Day 5	Building Design: Design Activity using Unity or blueprints
Week 2: Day 1 - 4	Dedicated time to work on the Project
Week 2: Day 5	Project presentation

Table. 1. Overview of the Camp Schedule

The paper presents the findings of a summer camp organized as a pilot project to incorporate the above-mentioned domains into a single project. The summer camp was called “VITAL Summer Camp 2016 <code your dream house>”. VITAL stands for Visualization, Informatics, Technology, Automation and Learning sciences. The goal for the students was to be able to design a building in virtual reality just through code. By creating the building through code, the students would only see the building after the code was executed. With the coding requirement, the students would need to be able to visualize the building design mentally or with the use of blueprints.

The VITAL Summer camp was conducted in order to introduce concepts from Programming, Virtual Reality, Construction, and 3D Visualization to High School students in an interdisciplinary format. The concepts would be taught in a curriculum that is structured after Project Based Learning. As can be seen on Table 1, the structure of the classes was divided into 3 types, a normal class day, a day dedicated to working on the final project, and a presentation. The first week was devoted to teaching the students the foundation in programming necessary to be able to complete the final project. The second week dealt with the students working on their project and later presenting the results of their labor.

Class days dealt with a core concepts and techniques followed by a short activity. The outcome of these activities would be to help the students understand and use these new concepts on a practical scenario, while also apply these concepts in Unity. By applying these concepts in a virtual space, they would see a visual representation of the work they have created. The core programming concepts and techniques that were taught on the first week were as followed: General programming syntax, objects, classes, data types, if statements, arrays, and loops. Along with basic programming knowledge, the students were challenged to approach the in class exercises differently. The goal wasn't just to complete the mini projects, but to complete them as efficiently as possible.

With all the general programming concepts learned, the students would tackle the final project. The project was designed so that the students had to implement at minimum one loop, one array, and one if statement. Asides from these requirements, the students were free to build any kind of building, or structure that they wished. Being only limited by their imagination, the students wished to implement tasks that required more advanced skills and techniques that were not apart of the curriculum. . The student's ideas motivated them to learn new concepts and techniques that were not part of the planned curriculum in order to reach their goals. By the middle of the second week, the students had each learned new techniques in Unity and programming that were shared amongst themselves. These new skills allowed for the students to create unique buildings, with unique features. One of the students wanted to be able to give a more realistic virtual tour of his building on the Unity software. This student created stairs that would trigger an event when the player would approach them. This event would allow the player to walk smoothly up the stairs in a more realistic way without the need of jumping.

The unique features that were implemented by the students increased their self-efficacy in the realm of programming. The sense of accomplishment expressed by these students as they learned an entirely new concept, that they originally felt impossible, increased their interest in programming. This new sense of confidence was displayed during their presentations. The students had great pride in their work which lead to them to continue working on projects to improve on them after the course ended. Examples of their work can be seen on Fig 2.

Fig. 2. Student Projects: Office building, Home, Giant

EDUCATIONAL CHALLENGES

Knowledge Silos

A challenge that many professionals face is that their knowledge is centered on their discipline and doesn't deviate into other fields of study (Vassigh, 2016). These disciplinary silos, or knowledge silos prevent professionals from approaching situations from different points of view (Vassigh, 2016). An objective of the course was to introduce the concept that interdisciplinary skills from fields such as Construction, and Computer Science can be used in unison to solve practical problems. In the case of the course, the students would combine concepts from Construction such as creating plans for their building, and programming from Computer Science in order to build the building efficiently. Virtual reality was also used in order to give the students a project that involved visualizing 3D objects in a virtual space. This type of activity in visualization also served to help refine the student's spatial visualization capabilities.

Construction: Technological Interests in Newer Generation

The students had virtually no experience in computer programming. These students also had no knowledge on how buildings are constructed, or what it takes to design them. The final project required for the students to be able to design a building, and then construct it on Unity. The design portion of the project required that the students use some measure of spatial visualization, which is a difficult task, even for Civil Engineering students who refine this particular skill (Alias, 2002). The construction portion showed how programming could be a beneficial tool to build a structure in a virtual environment. By constructing a building in a virtual environment, the building itself could be easier to perceive to others that have no training in Construction than by using spatial visualization from reading blueprints.

Engineering Plan Reading and Designing

Once the students gained the necessary knowledge to start the final project they then used different methods to approach the problem. Three of these methods stood out amongst the rest because of how much progress was made in a small amount of time. The methods involved, creating and using physical blueprints, using a virtual model, and using programming code to create a structure of any shape and size. Two of the three methods relied heavily on spatial visualization, while the other relied on programming and 3D visualization.

The first method was to design the building's blueprints on paper. The amount of planning and design involved in this method allowed the student to foresee potential issues before he even started building. The student relied on spatial visualization in order to conceptualize the building through the blueprints. Because of the blueprints, the building turned out to be very organized and intricate compared to the other buildings.

The second method involved using a pre-existing home that the student created in a videogame as a model that he then tried to recreate. The student did create a blueprint, but he mainly relied on the model for reference. With this model, he could visually see what he was creating which helped him in creating exactly what he wanted.

The final method involved creating a programming script that allowed the student to customize the building's structure into several rectangular shapes by having the user specify parameters of length, width and height. The product from this method wasn't as complex as the others, but the script was easily customizable suit the user's needs. This method relied solely on the student's mental visualization and imagination of the building.

Computer Programming Challenges

The students that signed up for the course had little to no programming experience. Two of the students had just started taking an entry level programming course at the start of the first week of the course. These students still had little to no knowledge of programming. They each came with different levels of interest, but as a whole the group wanted to learn how to create a virtual environment. A challenge that was faced early on was to show the students that using programming to create multiple structures on Unity was greatly beneficial. This task was tackled by having the students create a brick wall. With code, a brick wall of any size could be created with a small amount of programming. Then, by altering the code with mathematical logic, then the wall could be edited in any specific way.

Some of the students originally felt that programming would be beyond their ability. When the final project was introduced by the teacher, and the first programming concepts were introduced, the students expressed that programming was beyond their grasp. These students had a low level of self-efficacy. This low level of self-efficacy made it difficult for these students to grasp the concepts within the first day or two of the course. The difficulty arose not just from the material, but because they felt that they weren't able to accomplish the tasks laid out before them (Bandura, 1993). However, because of the collaborative learning environment within the class, and the students hard work, they were able to learn the concepts that were presented. After the first week the students felt more confident in their ability to code, and were able to tackle the final project head on. By the end of the program, these students managed to complete the project and gain a great sense of accomplishment. These students also gained a higher level of self-efficacy throughout the course because they were also able to learn concepts and techniques from outside sources. These concepts ranged from clever coding practices to extra utilities in Unity that were not covered in the curriculum.

Spatial Visualization Abilities and Strategies

Spatial visualization is a key factor in engineering fields. Spatial visualization is a useful skill that allows engineers to represent designs, and communicate them to others more clearly (Allam, 2009). It's a key skill that allows engineers to reason over concepts such as strain, fluid-flow and stress on buildings (Allam, 2009). This ability may be essential learning to solve problems in civil engineering in topics such as structural design, engineering mathematics and soil mechanics (Alias, 2002). Designers must be able to visualize buildings from blueprints before they begin building. Although Spatial visualization is taught to engineers through their studies, it could be beneficial to be introduced earlier. In the VITAL camp, students are introduced to spatial visualization when they are tasked to construct a building in virtual reality (VR). An example of a student's progress designing a home is found in Figure 3.

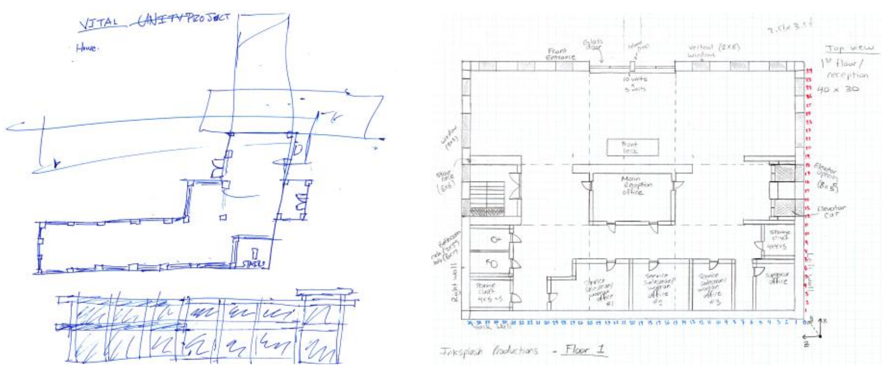

Fig. 3. Progress of the plans throughout the program: Beginning of the camp (left) and end of the camp (right)

Collaborative Learning Environment

The students worked on their activities in an environment where they would be able to communicate freely. This environment allowed for the students to help each other when learning the concepts, and while designing their buildings. This collaboration created social networks among the students (Brewe et al, 2009). The students who collaborated also provided different points of view and different sources of experience. These students provided help for solving tasks that their classmates might have had issues with. This social network created peer to peer interactions that were beneficial for the students to reinforce concepts that they didn't fully understand. A visual representation of this social network is displayed in Figure 5.

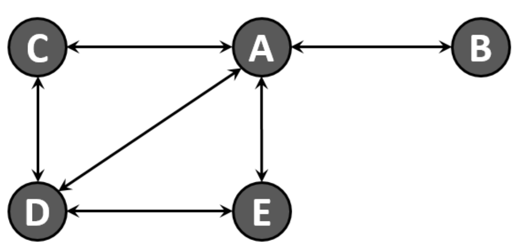

Fig. 5. Visual representation of the collaborative learning environment among the students.

Student	Attitude	Self-efficacy	Collaboration & interaction	Planning	Quality of Product
A	Was very eager to learn the material, but was having trouble getting some concepts.	Originally felt that the material was too challenging, but was willing to learn something	Collaborated extensively with the others.	Spent much time designing the layout of the house	High 5/5
B	Was very eager to learn the material, and was understanding concepts quickly.	Thought the materials was difficult, but doable	Did not collaborate too much	Spent much time designing the algorithm	High 5/5
C	Was very eager to learn the material, but was having trouble getting some concepts.	Originally regretted signing up for the class because the material seemed beyond his capabilities.	Collaborated extensively with the others.	Spent the most time designing the house on paper	High 5/5
D	Was very eager to learn the material	Wanted to learn a new skill regardless of what it was.	Collaborated with the others	Didn't plan much, but tried to make something more creative	Good .4/5
E	Was very eager to learn the material, and was understanding concepts quickly.	Thought the materials was difficult, but doable	Collaborated with the others	Spent more time designing the algorithm and designed as he went along	Good 4/5

Table. 2. Student Outcome Matrix

The students that collaborated the most, like student A as seen on Table 2, had a similar programming structure, and building thought process. The two styles of construction were based on whether the student had a plan to build a specific building, or created an algorithm to work with any building. Among the students, student B collaborated the least while the others collaborated greatly with each other. Student B chose approach the project differently from the other students. He decided to create a modular algorithm. This particular student approached the project from a Computer Science standpoint, while the others approached the project from a Construction standpoint. Student B created a completely modular home that could be altered to create square or rectangular house of any size. The other students instead would plan how their house would look, with either a blueprint, or a model. Then these students would try to recreate the building. Through this social network, the collaborators completed the project in a similar way, while the outsider completed the project in his own way.

DISCUSSIONS AND RECOMMENDATIONS

Since the camp was designed as a pilot study, it was not necessary to have a large class size. Deep and meaningful feedback from the students was important to improve the curriculum for the future implementation of the program. Regardless of the class size, the students responded positively to the program, and were able to have numerous interactions. They were motivated to learn foreign concepts that seemed "impossible" in their beginner's eyes, and were able to create unique projects in a short amount of time. The results of the pilot study showed promise; however, the scale of the study will be increased next year to obtain a more meaningful sampling of data. The length of the camp could be increased, which would allow for more concepts to be introduced, virtual reality would have a bigger focus, and the class could potentially become a college course itself. The camp focused on construction, and had elements from programming and virtual reality included. The short two-week camp resulted in students receiving a more condensed curriculum. If the camp lasted more than two weeks, then it could have taught the students more concepts, and helped them test out more complex projects. Some of the students continued to work on their projects after the camp ended, and were able to improve greatly on them after just a few days. The program could also be adapted into a college course for beginning programmers. Many students struggle with the first programming courses in college. (Adu-Manusarpong et al, 2013). A possible solution could be to repurpose this course into an entry level interdisciplinary course for construction students. The course could be a way to teach the basics of programming and logic that are needed for students to be successful in the beginning programming courses

(Adu-Manusarpong et al, 2013). The course brings awareness to students that technology could be applied to the field of construction in order to solve problems in interesting ways.

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