# Simulation Technology and Student Engagement

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## Abstract

An authentic learning environment with the integration of technology can effectively engage students and improve their academic performance. Technology can support learning situations that relate to real life, and provide opportunities for inquiry and collaboration, fostering engagement. This paper will provide details of an authentic learning environment that utilizes flight simulation software to engage middle school students in the learning of several math and science concepts. Active learning lessons were developed using missions flown on the flight simulator. The pedagogical approach was implemented in a one-week long summer camp for students from rural counties with low socio-economic status. Data on student attitudes towards STEM was collected using a 65-item questionnaire. The performance on the content taught during the camp was also measured. The pre-post data analysis indicated positive impact of the approach. The results of this study will be included in this paper. This work is supported by NSF Grant# 1614249.

## Introduction

The Program for International Student Assessment (PISA) measures mathematics, science and reading skills of 15-year old students. Students from almost 80 countries participated in the 2018 administration of PISA. The NCES[1] reported that the average score of US students in science was higher than the average score of the students from the Organization for Economic Cooperation and Development (OECD) countries, but it was lower than six of the 36 countries of the OECD. The performance of US students in math literacy was more concerning. The average score of US students in math was lower than the average score of students from the OECD countries. This latest performance is not much different than past performance of US students. The performance of US students in science and math is a cause of concern since it may have long term impact on the technological leadership of the US.

The performance of students from low socio-economic strata that has a disproportionately large number of African-Americans is much lower than White students[2]. The impact of this ‘achievement gap’ becomes evident in the lower numbers of African-Americans engaged in the STEM workforce in comparison to their percentage of the US population. African-Americans with a minimum of bachelors’ degree are only 9% of the STEM workforce[3].

An important aspect of improving US students' performance is firing up student interest in STEM. The decline in interest in STEM was been reported by Potvin and Hasni[4] who surveyed almost 1900 students from 5th through 11th grades. They noted that students preferred arts and physical education as compared to science and technology. They also observed that interest in science and technology reduced with increasing age, although this seemed to be the case for all subjects. As noted in another survey[5], the percentage of 13-17 years old male students interested in STEM has dropped from 36% to 24% from the previous year. It was also indicated in the survey that only 11% girls were interested in STEM and this number has held steady over the years. VanMeters-Adams et al.[6] noted that extracurricular activities play an important role in attracting students to STEM. In a survey conducted by Randstad[7], it was observed that 56% of the respondents (11-17 years old) were of the opinion that if STEM content in the classroom was more connected to its real-world use, it may increase interest.

Engagement with content and the learning environment is essential to learning. The learning experience needs to be designed to engage students cognitively for deeper learning but also to engage them affectively, and behaviorally. A cognitively engaging learning experience should include authenticity, inquiry and collaboration[8]. Several impacts of the use of technology in a learning environment have been recognized[9] including equity, and accessibility. An appropriate use of technology can facilitate the design of a cognitively engaging learning environment. The impact of simulations on learning is well documented[10, 11, 12]. Specifically, simulation technology can present authentic scenarios, provide an opportunity for inquiry (collect, analyze and interpret data), and foster collaborative learning[13, 14, 15].

This paper discusses the impact on the attitudes towards STEM of middle school students who experienced a week-long summer program which used a flight simulator to teach certain math and science concepts. The research questions guiding this study were:

*To what extent does an active-learning environment such as a flight simulation-based approach impact the attitudes of middle school students towards STEM?*

*To what extent does an active-learning environment such as a flight simulation-based approach impact the learning outcomes of middle school students?*

## Method

The study was a quasi-experimental repeated measures design. The study consisted of a week-long day-camp during the summer. The participants (N = 25) of which 4 were males and 21 were females, were middle school students with low socio-economic status, and from two rural counties. The authors introduced the summer program during the academic year to middle school teachers to assist in recruitment of participant students. The summer camp was hosted at Tuskegee University. The camp was designed to engage students in various activities including the learning of specific concepts from math and science. The concepts to be learned during the summer camp were chosen based on the recommendation of the teachers with whom several meetings were held during the development of the study.

The theoretical bases of the design of the study are cognitive engagement and self-efficacy. Thus, the learning environment was based on authenticity, inquiry and collaboration. Flight simulation software was used to engage students in a real word scenario. Flight data was collected by the students, processed, analyzed and interpreted by the students. Teams of two students while flying their own missions were provided the opportunity to discuss their data analysis. Next, students were engaged in a discussion about the data analysis and interpretation. The math concepts studied during the camp were the Pythagorean theorem and similar triangles, while the science concept investigated was the standard atmosphere. The mission associated with the math concepts was a landing approach in a Cessna 172 aircraft and with the science concept, a climbing flight in an F-18 was used. The learning approach was designed on the "5 Es" methodology[16]. Thus, students were first explained some basic concepts followed by paper-pencil activities. The students then flew the 'mission' to collect 'real-life' data and respond to questions that required analysis and interpretation of the data. During the summer camp the participating students learned the basics of the physics of flight, aircraft controls and flight instruments. They were also instructed on how to use formulas and plot data in Excel. Academic related activities such as 'Jeopardy' were included in the camp.

The participants were administered a 65-item Likert-scale at the start of the camp to measure their attitude towards STEM. The responses to the survey were on a scale that measured strong agreement (SA, 5), agreement (A, 4), neutral (N, 3), disagreement (D, 2) and strong disagreement (SD, 1) with a statement. The same survey was administered to participants at the end of the week-long camp. The survey loaded on five dimensions which are (a) Math Importance (9 items), (b) Math Enjoyment (14 items), (c) Science Importance (9 items), (d) Science Enjoyment (15 items), and (e) Math and Science Instruction (18 items). There were several negative questions in the survey that were reversed scored. Analysis of the responses was carried out using a repeated-measures (paired samples) two-tailed t-tests with a $p < 0.05$ to test the null hypothesis ($H_o$).

$H_o$: "*the active-learning environment using the flight simulator had no impact on the attitudes of the students towards STEM*"

Students were also administered pre and post tests on the contents for each math and science topic covered during the summer camp. The content tests included 15 questions each on the math and science concepts learned during the summer camp. The tests questions were a mix of multiple choice and word problems.

## Results and Discussion

The following observations were made based on the data analysis. The intervention had a statistically significant impact on the attitudes of the students who participated in the summer camp with a $p < 0.05$, thus rejecting the null hypothesis ($H_o$). A summary of the mean ($\mu$), and the standard deviation ($\sigma$) of the responses for each dimension is provided in Table I.

Table -I: Summary of Pre-Post Analysis

| Dimension | Pretest | | Posttest | | p |
|---|---|---|---|---|---|
| | μ | σ | μ | σ | |
| Math importance (I) | 3.83 | 0.65 | 4.22 | 0.46 | < 0.0005 |
| Math enjoyment (II) | 3.44 | 0.69 | 3.72 | 0.63 | < 0.005 |
| Science enjoyment (III) | 2.96 | 0.62 | 3.45 | 0.65 | < 0.0001 |
| Science importance (IV) | 3.43 | 0.55 | 4.01 | 0.65 | < 0.0001 |
| Math & Science Instruction (V) | 3.35 | 0.41 | 3.91 | 0.46 | < 0.0001 |

*Dimension I (Math Importance)*. The average responses to each of the statements of this dimension are given in Fig. 1. The pretest mean of responses of this dimension was 3.83 and the posttest mean was 4.22. The change was statistically significant with $p < 0.0005$. Out of the nine items in this dimension, six items had statistically significant positive changes at $p < 0.05$. These items (#1, 2, 6, 7, 8, 9) are given below.

1. There is little need for mathematics in most jobs. (Reversed scored)
2. Mathematics is helpful in understanding today's world.
6. I would like a job which doesn't use any mathematics. (Reverse scored)
7. It is important to me to understand the work I do in mathematics.
8. Mathematics is useful for the problems of everyday life.
9. Most people should study some mathematics.

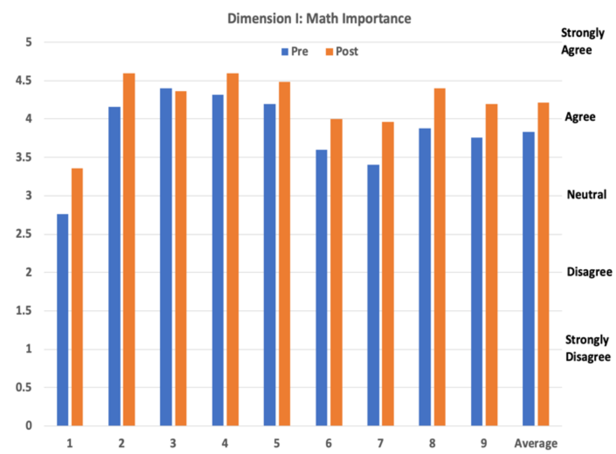


Figure 1: Math importance dimension

*Dimension II (Math Enjoyment)*. The averages of the responses to the statements of this dimension are given in Fig. 2. The pretest average for the dimension was 3.44 and the posttest average was 3.72, with a $p < 0.005$. Of the 14 items in this dimension, items #1, 2, 10 given below were statistically significant at $p < 0.05$.

1. Mathematics is something which I enjoy very much. ($p < 0.02$)
2. When I hear the word mathematics, I have a feeling of dislike. (Reverse scored), ($p < 0.0005$)
10. It makes me nervous to even think about doing mathematics. (Reverse scored), ($p < 0.02$)

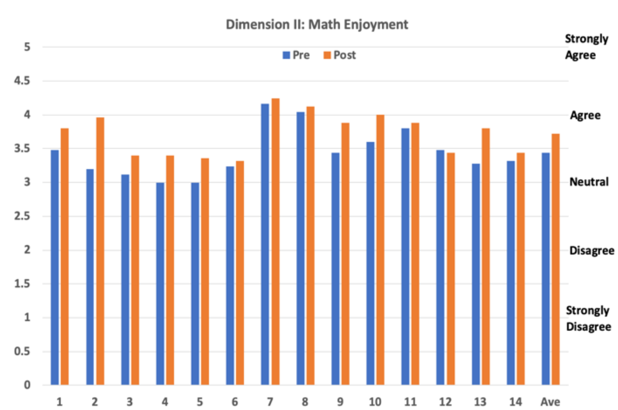


Figure 2. Math enjoyment dimension

*Dimension III (Science Enjoyment)*. The pretest average for the responses of statements of this dimension was 2.96 and the posttest average was 3.45. The change in the means was significant at $p < 0.0001$. The average responses to each of the statements of this dimension are given in Fig. 3. Of the 15 items in this dimension, items # 1, 3, 4, 5, 6, 10, 14 which are given below registered a statistically significant improvement.

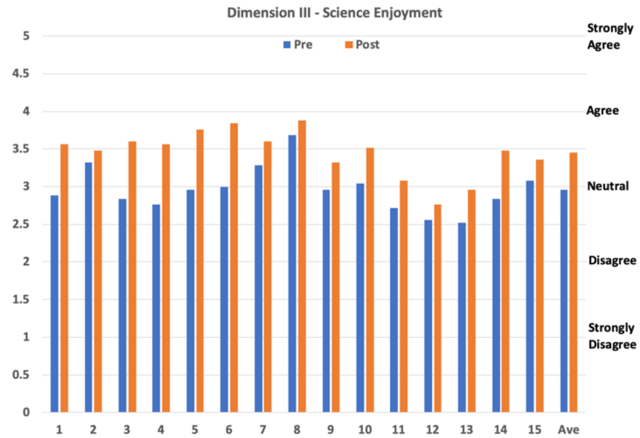

Figure 3. Science enjoyment

1. I don't do very well in science. (Reverse scored), ($p < 0.005$)
3. Science is easy for me. ($p < 0.005$)
4. Sometimes I read ahead in my science book. ($p < 0.001$)
5. I feel uneasy when someone talks to me about science. (Reverse scored), ($p < 0.001$)
6. I have a real desire to learn science. ($p < 0.05$)
10. Science is something which I enjoy very much. ($p < 0.005$)
13. I would like to spend less time in school doing science. (Reverse scored), ($p < 0.01$)
14. When I hear the word science, I have a feeling of dislike. (Reverse scored), ($p < 0.01$)

*Dimension IV (Science Importance)*. This dimension had seven items. The pretest average for the dimension was 3.43 and the post test average was 4.01. The change was statistically significant at $p < 0.0001$. Averages to responses to the statements of this dimension are given in Fig. 4. The increases in average responses to items #1, 2, 3, 4, 5, were statistically significant. These items are given below.

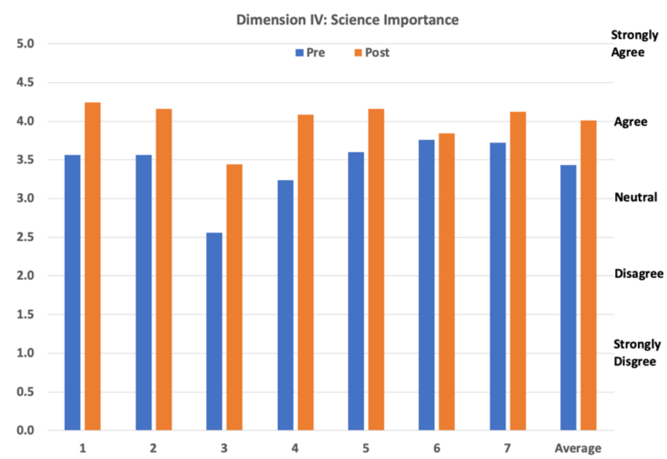

Figure 4. Science importance

1. Science is useful for the problems of everyday life. ($p < 0.001$)
2. Science is of great importance to a country's development. ($p < 0.005$)
3. I would like a job which doesn't use any science. (Reverse scored), ($p < 0.005$)
4. You can get along perfectly well in everyday life without science. (Reverse scored), ($p < 0.0005$)
5. It is important to me to understand the work I do in science. ($p < 0.05$)

*Dimension V (Math and Science instruction)*. This dimension consisted of 18 items. The averages of the responses to these items are shown in Fig. 5. The average of the pretest on this dimension was 3.35 while the posttest was 3.91. The increase in the mean was statistically significant with a p < 0.0001. The increases in the mean responses to items #1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 14, 18 which are given below were statistically significant.

1. Solving mathematics problems is fun. (p < 0.01)
2. Most people should study some science. (p < 0.01)
3. No matter how hard I try, I cannot understand mathematics. (Reverse scored), (p < 0.01)
5. I remember most of the things I learn in mathematics. (p < 0.005)
6. I would rather be given the right answer to a mathematics problem than to work it out myself. (Reverse scored), (p < 0.01)
7. I have a real desire to learn mathematics. (p < 0.05)
8. If I don't see how to do a science problem right away, I never get it. (Reverse scored), (p < 0.0005)
9. I would rather be given the right answer to a science problem than to work it out myself. (Reverse scored), (p < 0.05)
10. If I don't see how to do a mathematics problem right away, I never get it. (Reverse scored), (p < 0.05)
11. I usually understand what we are talking about in mathematics. (p < 0.0005)
14. I am good at doing mathematics problems. (p < 0.005)
18. I think using the flight simulator to learn math can help students learn the concepts. (p < 0.01)

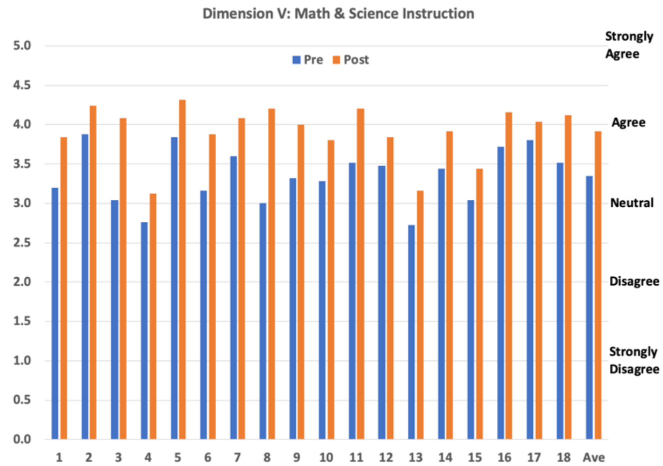

Figure 5. Instruction dimension

As can be observed from the above data analysis, the intervention of using a flight simulator to teach math and science concepts had a positive impact on the attitudes of the participating middle school students toward math and science.

The pre-post results of the content tests for the math and science concepts were used to determine the impact of the approach on student learning. These results are shown in Fig. 6 and Fig. 7.

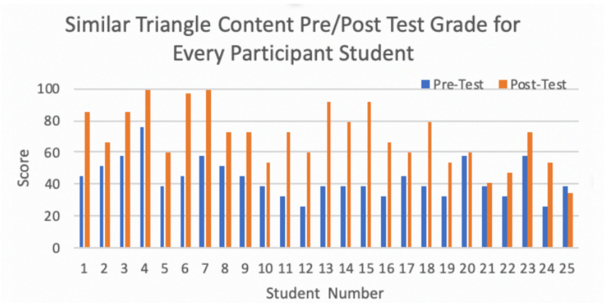


Figure 6. Pre-post Comparison of Math Content Knowledge

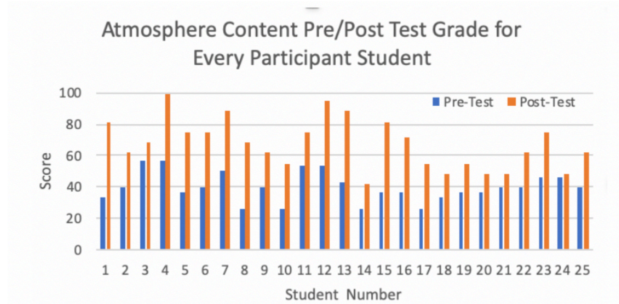


Figure 7. Pre-post Comparison of Science Content Knowledge

The changes in the performance between pretest and posttest in both math and science indicate an increase in the learning outcomes.

## Summary and Conclusions

The results of this study demonstrated the effectiveness of an authentic learning environment (using a flight simulation software). The environment engaged students in the behavioral and affective (or emotional) domains along with the cognitive domain. Based on the results of the math and science content tests, the approach also had a positive impact on reinforcing student content knowledge. The simulation technology can thus be effectively used to provide a real-life learning environment, engage students and strengthen the concepts.

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