Technology-Supported Learning Environment and its Impact on Attitudes Towards STEM

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Abstract

Integration of technology in a learning environment has a positive impact on student engagement, motivation and attitude towards Science, Technology, Engineering, and Math (STEM). Middle school students from underrepresented groups in STEM participated in a one-week long summer camp using an innovative technology supported intervention. They learned selected math and physics concepts using hands-on activities with flight simulation software. Additional components of the camp included learning about the physics of flight and the use of spreadsheets to analyze data collected from the flight simulator. The participants were also provided with talks on emerging STEM careers and they interacted with undergraduate student mentors. A within-subject repeated measures (pre-post) quasi-experimental design was used. Participants attitudes were measured with a 65-item survey that provided data on five dimensions of attitudes towards STEM. Similarities and differences between male and female participants on the survey items and the five dimensions were observed.

Keywords

Attitudes, STEM, middle school, active learning

Introduction

The performance in math and science of K-12 students from the US is low in comparison to the industrialized nations as seen from the results of international assessments. For example, according to the 2015 PISA Report[1], US 15-year-olds scored significantly lower than seventeen industrialized countries in science, and more alarmingly, their performance in mathematics was significantly lower than 37 countries. A more granular look at the data glaringly brings out the achievement gap within the US K-12 student population. Data from the same PISA Report showed that Blacks and Hispanics scored significantly lower than the White students. This ethnically/racially stratified performance is seen in both PISA[2] and US National assessments[3].

Several reasons have been cited in research literature for the low academic performance of middle school students such as economic disparity[4] and engagement with the learning materials. It has been reported[5] that 82% of high school students are sometime or most of the time bored in the classroom. Incorporating technology in the classroom is commonly considered to be an effective method to engage students. However, while the use of technology may influence the affective dimension of engagement, it may not impact the cognitive engagement of students, hence not yielding the expected result. Therefore, in addition to structural challenges that contribute to the students' less than acceptable performance, there are academic and pedagogical challenges that need to be addressed. This work that is funded by the Innovative Technology Experiences for Students Teachers program of the National Science Foundation

(Grant # 1614249), focused on how a deliberately designed learning environment that is supported by an innovative use of technology impacts students' attitudes toward STEM. The data was gathered through pre-post surveys and analyzed to determine the changes in attitudes of the participants. The impact of the use of the flight simulator on affective and cognitive engagement was assessed. This paper however presents results of the impact on the emotional (self-efficacy) and attitudinal domains of engagement.

Method

Participants

The project used flight simulation software to provide hands-on active learning opportunities to 7-8 grades students (N = 26) from two rural counties of Alabama. Data is presented for 25 students, N=25 (Male = 11, Female = 14) as one student did not take the post-test. All participating students were from underrepresented groups and self-identified as African-American.

Materials

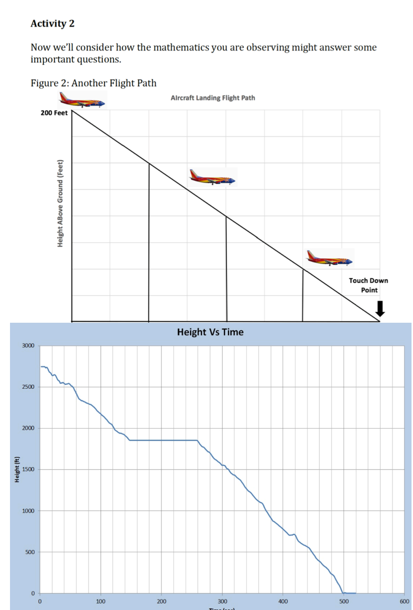
The intervention consisted of a one-week long summer camp. The camp consisted of several activities mainly learning and reinforcing some concepts of math and physics, and experiencing the connections of these concepts with real life through flying specially designed mission on the flight simulator using Microsoft FSX (Fig. 1). The participants also learned about physics of flight and how to use spreadsheet to import, graph and analyze the recorded data from the flight mission.

Figure 1: Flight simulator

The following four lessons were developed for the flight simulator. Additional lessons are being developed. Details of each lesson modules are included in the project website (www.flyhightu.weebly.com).

(a) Ratios and Proportion
(b) Kinetic Energy and Potential Energy
(c) Slope and Rate of Change
(d) Newton's Laws

However, only the Ratio and Proportion, and Kinetic Energy and Potential Energy lesson modules were covered in the one-week summer program. Participating student learned the concepts through paper-pencil exercises. Subsequently, they compared data collected from the flight simulator mission to understand the linkages between concepts and real life (Fig. 2).



Procedure

A repeated-measures within-subject (pre-post) experimental design was used. A 65-item math and science attitudes survey instrument was administered to the participants at the start and then at the end of the one-week camp. participants' Figure 2. Example of hands-on activity attitudes using a 5-point Likert scale from strongly disagree (1) to strongly agree (5).

Figure 2: Hands-on Activity

Based on the factor loadings, five (5) dimensions were identified from the attitudinal survey instrument: (1) *Mathematics Importance and Usefulness (D1)*; (2) *Mathematics Enjoyment and Aptitude (D2)*; (3) *Science Enjoyment and Aptitude (D3)*; (4) *Science Importance and Usefulness (D4)*, and (5) *Math and Science Instruction (D5)*.

Results

A pre-post correlated samples two-tail t-test of responses of all the participants (males and females) to the following questions resulted in statistically significant differences in the means at a $p<0.05$. The questions and the pre-post means for these questions are reported in Table 1.

Dimensions and its elements	Means of Responses	
	Pre	Post
D1: Mathematics Importance and Usefulness (9 elements) • Mathematics is of great importance to a country's development	4.4	4.72
D2: Mathematics Enjoyment and Aptitude (15 elements) (no statistically significant difference on any question)	-	-
D3: Science Enjoyment and Aptitude (15 elements) • I would like to do some outside reading in science	3.36	3.72
D4: Science Importance and Usefulness (9 elements) • Science is useful for the problems of everyday life	4.08	4.44
D5: Math and Science Instruction (17 elements) (no statistically significant difference on any question)	-	-

Table 1: Pre-Post Analysis of Responses of All Participants

The data was then analyzed to determine if gender played a role in the effectiveness of the intervention. Difference in mean responses by gender to the pretest survey questions that were significant at $p < 0.05$ are given in Table 2 below.

Dimensions and its elements	Means of Responses	
	M	F
D1: Mathematics Importance and Usefulness (9 elements) • It is important to know math to get a good job	4.82	4.21
D2: Mathematics Enjoyment and Aptitude (15 elements) • Sometimes I read ahead in my math book.	3.09	4.00
D3: Science Enjoyment and Aptitude (15 elements) (no statistically significant difference on any question)	-	-
D4: Science Importance and Usefulness (9 elements) • It is important to me to understand the work I do in science	4.00	3.57
D5: Math and Science Instruction (17 elements) • I think using the flight simulator can help students learn math & science concepts	4.46	3.57

Table 2: Pretest Analysis of Responses by Gender of Participants

Post-test data by gender for which there was a statistically significant difference ($p<0.05$) is reported in Table 3. For comparison, the pretest means for these post-test questions have been included in parenthesis.

Dimensions and its elements	Means of Responses	
	M	F
D1: Mathematics Importance and Usefulness (9 elements)		
• Math is useful for problems of everyday life	4.27 (4.55)	4.79 (4.29)
D2: Mathematics Enjoyment and Aptitude (15 elements)		
• Sometimes I do more math problems than given in class	3.09 (3.09)	4.00 (3.36)
• It scares me to take math	2.36 (2.00)	1.64 (1.79)
• I have a good feeling towards math	3.55 (3.91)	4.50 (4.00)
• I feel uneasy when someone talks to me about math	2.82 (2.51)	1.86 (2.21)
• It makes me nervous even to think about math	2.46 (2.09)	1.57 (1.93)
D3: Science Enjoyment and Aptitude (15 elements)		
• When I hear the word science, I have a feeling of dislike	2.36 (2.09)	3.00 (2.29)
D4: Science Importance and Usefulness (9 elements)		
(no statistically significant difference on any question)	-	-
D5: Math and Science Instruction (17 elements)		
• I would rather be given the right answer to a science question than to work it out myself	3.00 (2.00)	1.93 (2.29)
• I have a real desire to learn math	3.64 (3.19)	4.43 (4.14)

Table 3: Post-test Analysis of Responses by Gender of Participants

The pre-post responses of the participants were analyzed by gender to determine the impact of the intervention. These results are provided below in Table 4 for male participants and in Table 5 for female participants.

Dimensions and its elements	Means of Responses	
	Pre	Post
D1: Mathematics Importance and Usefulness (9 elements)		
• There is little need for math in most jobs	2.91	2.28
• It is important to know math to get a good job	4.82	4.00
D2: Mathematics Enjoyment and Aptitude (15 elements)		
• When I hear the word math, I have a feeling of dislike	2.46	2.82
D3: Science Enjoyment and Aptitude (15 elements)		
• Solving science problems is fun	4.00	3.64
D4: Science Importance and Usefulness (9 elements)		
• It is important to know science to get a good job	4.09	3.36
D5: Math and Science Instruction (17 elements)		
• I would rather be given the right answer to a science question than to work it out myself	2.00	3.00

Table 4: Pre-Post Analysis of Responses for Male Participants

Dimensions and its elements	Means of Responses	
	Pre	Post

D1: Mathematics Importance and Usefulness (9 elements) (no statistically significant difference on any question)	-	-
D2: Mathematics Enjoyment and Aptitude (15 elements) • I have a good feeling towards math	4.00	4.50
D3: Science Enjoyment and Aptitude (15 elements) (no statistically significant difference on any question)	-	-
D4: Science Importance and Usefulness (9 elements) • Science is useful for the problems of everyday life	4.00	4.57
D5: Math and Science Instruction (17 elements) • Using the flt. sim. in the class is a fun way to learn math and science concepts • I think using the flt. sim. can help students learn science concepts • I think using the flt. sim. can help students learn science concepts	3.71 3.71 3.57	4.64 4.43 4.71

Table 5: Pre-Post Analysis of Responses for Female Participants

The overall percentage change in attitudes for females and males in each dimension was also compared as shown in Table 6.

Dimensions	%Change F/M
D1: Mathematics Importance and Usefulness	+15/-3
D2: Mathematics Enjoyment and Aptitude	+20/-12
D3: Science Enjoyment and Aptitude	+1/-3
D4: Science Importance and Usefulness	+2/-3
D5: Math and Science Instruction	+4/-5

Table 6: Pre-Post Average %Change in Each Dimension

The post-camp survey provided qualitative insight into the participants' response to the camp. Some representative responses are given below.

- I love this camp and I hope they have it next year because I enjoyed this program
- Overall, I think the camp changed my perspective on math
- I liked this camp and would like to come back
- I really loved the camp and the experience

Discussion

The pre-post analysis (Table 1) of the combined data of the male and female participants indicated a statistically significant improvement in attitudes of the participants on only three of the five dimensions, although this improvement was only in one element in each of the dimensions. This prompted a deeper look at the data by analyzing it by gender. The gender-based analysis provided interesting insights into the impact of the intervention on females and males.

However, before the impact of the intervention was analyzed by gender, the pre-intervention attitudes were analyzed by gender to establish a base line. There were statistically significant differences in pretest responses based on gender on four of the five dimensions (Table 2), albeit again this change was in only one element of each dimension. Of the five dimensions, males had higher percentage of mean responses on elements of three dimensions D1, D4, and D5. Female participants had higher percentage of mean responses only on the elements of D2. There was no significant difference between males and females on the pretest in dimension D3.

Statistically significant differences based on gender on more questions of the various dimensions on the post-test were observed (Table 3). The post-test data showed that the intervention had a statistically significant positive impact on the self-efficacy of female participants in comparison to the male participants. For example, the female students mean response was more towards the ‘strongly disagree’ in response to the question “It scares me to take math” as compared to the male students.

Although in the pretest, the response to the question of the importance of the need for math in most jobs was statistically significantly higher for males (Table 2, D1), the analysis of the post- test to the same question showed no statistically significant difference between males and females. However, the importance of this element increased for male participants based on the post-test results.

The pre-post analysis of responses for male participants (Table 4) showed that in dimensions D2, D3, D4, and D5, the attitudes changed in the negative direction. For example, in dimension D2, the post-test response to the question ‘*when I hear the word math, I have a feeling of dislike*’ was more towards agreeing with the statement as compared to the pretest. However, the response to the question ‘*there is little need for math in most jobs*’ in D1 moved in the positive direction. These results indicate that the intervention did not have an overall positive impact on male students.

The pre-post analysis of responses for female participants (Table 5) indicated positive impact of the intervention in dimensions D2, D4, and D5. There was no significant change in D1 and D3. Therefore, based on these results from Tables 4 and 5, one can conclude that the intervention had an overall positive impact on only female students.

Based on the comparison between females and males on their pre-post responses to each dimension (Table 6), the changes were on the average in the positive direction for the females while they were in the negative direction for the males. For example, the percentage change in D1 was positive (by 15% change) for females as compared to the negative (by 3% change) for males. This unexpected outcome of the intervention which was the movement of the attitudes of the male participants in the negative direction, could be because of a smaller number of male participants. The disinterest of some of the male participants (which was observed during the camp) may have also contributed to this negative result.

As a summary, the intervention in general had a positive impact on attitudes for mainly female students. In addition, the analysis did not show statistically significant changes in the responses to most of the survey items and this overall result may also be due to the small number of participants.

Future Work

The project will conduct additional summer camps with the design as reported in this paper. The additional data that will be collected, will increase the statistical power of the sample and the results will be more robust.

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