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Impact of an Authentic Environment on Learning of Math and Science

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Abstract

The paper provides details of a teacher professional development workshop on an authentic learning environment incorporating lessons based on hands-on activities on a flight simulator. The workshop design was based on best practices for teacher Professional Development (PD). The attitudes of teachers towards the use of technology were measured during the PD and are shared in this paper. Subsequently, a summer camp using the same learning environment was conducted for middle school students to learn selected math and science concepts. The results of the impact on the student participants of the summer camp are also presented in this paper. The participants learned the use of spreadsheets to analyze and plot data collected during the hands-on activities with the flight simulator. A within-subject quasi-experimental design (pre-post) was used to measure changes in attitudes towards Science, Technology, Engineering, and Math (STEM). The changes in content knowledge of the selected math and science concepts were also measured. Analysis of the pre-post responses to a 65-item STEM-attitudes survey provided interesting insight into the differences between males and females in their attitudes. Analysis of the pretest and post-test results of the math and science concepts instrument indicated the effectiveness of the intervention on math concepts.

Keywords

Attitudes, STEM, middle school, mathematics, science

Introduction

The US currently faces a challenge of educating sufficient number of students with interest in pursuing STEM-related careers. US students continue to perform at levels well below of those from other industrialized nations as demonstrated by the data of 2015 PISA Report[1]. According to this report, US students score in science was lower than seventeen industrialized countries. The performance of US students was even worse in math, in which they scored lower than thirty-seven of the countries whose students took these international assessments. Nationally, this achievement gap is mirrored in the lower performance of African-Americans and Hispanics students in comparison to White students as seen in both the PISA Report[2] and national assessments[3]. There are several reasons cited in literature[4-6] for this achievement gap. Some of these reasons are socio-economic status, strength of curriculum and disparity between school districts. In addition to these structural challenges, student engagement and motivation play an important role in learning. The pedagogical approach in the classroom has a strong impact on students' engagement with the learning materials. Students' cognitive engagement with the learning materials increases if they recognize relevance of the subject matter. Unfortunately, providing such a learning environment remains a challenge as evidenced by the 2014 report of the High School Survey of Student Engagement[7]. It was reported that 82% of high school students are sometime or most of the time bored in the classroom. Authentic learning environments, one that provides connections between the concepts being learned and its real-life applications and utility therefore need to be designed to increase students' engagement[8, 9, 10, 11]. With the availability of low-cost computers and physics-based simulations, such authentic environments can be implemented for the learning of math and science concepts.

Unfortunately, rural school districts face several challenges regarding access to professional development (PD) activities[12, 13]. These structural challenges impede the ability of rural teachers to be exposed to best practices of teaching in a technology rich environment that promotes authentic learning opportunities for students.

This paper provides preliminary results of the impact of an authentic learning environment that has been designed through an innovative use of flight simulation software. The target population of this work is middle school teachers and students from a rural county in Alabama who are from underrepresented groups. This work has been funded by the National Science Foundation through the Innovative Technology Experiences for Students and Teachers program (Grant # 1614249). The objective of the research was to measure the impact of the learning environment that was part of a week-long intervention on the attitudes of camp participants towards STEM and their improvements in content knowledge.

Method

Participants

The project used flight simulation software to provide PD to the middle and high school math and science teachers (N = 15, Males = 3, Females = 12) and hands-on active learning opportunities to 7-8 grades students (N = 26) from two rural counties of Alabama. Attitudinal survey data is presented for the 15 teachers who attended the week-long summer PD. Data is also 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.

Figure 1a: Large Screen Flight Simulator Setup   **Figure 1b: Landing Approach**

Materials

The Microsoft flight simulator software MSFSX was used for the hands-on activities. Since flying even a flight simulator can be a challenging task, the 'missions' associated with the various the math and science concepts were specially designed using the Cessna 172 aircraft. Flying these specially designed missions ensured collection of useful data for later use by the students. For example, the 'straight and level' flight that is used to collect data for studying slopes and rates of change allows manipulation of only the throttle. The heading, attitude and altitude are maintained automatically through the software. A shareware flight data recorder is used to record the flight data to a file. These flights can be used on individual desktop PCs running MSFSX. The large-screen flight simulator setup uses four PCs, three of which drive the three large-screen displays while the fourth is the master computer driving the instrument panel and the simulation (Fig. 1). The large screen setup was used to provide exciting flying opportunities to cities around the globe.

The teacher workshop design was based on best practices for professional development[14]. The teachers were provided with lesson plans that used the flight simulator to teach some math and science concepts. These concepts were identified through discussions with some of the teachers of the local middle schools during the academic year who also participated in the PD. The input from the teachers was an important element of the development process of the learning modules since one of the objectives of the project is that teachers should implement the method in their classrooms. The selected concepts were then linked to the specially designed hands-on activities on the flight simulator.

Several lessons are planned for development under the grant. In the first year of the grant, the following four lessons were developed with the incorporation of the flight simulator activities.

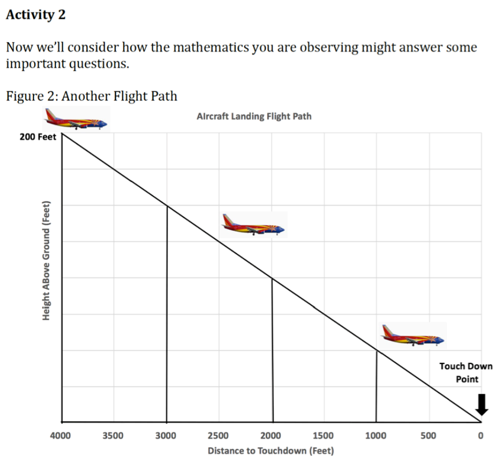
(a) Ratios and Proportion
(b) Slope and Rate of Change
(c) Kinetic and Potential Energy
(d) Newton's Laws

During the one-week PD and the summer camp for the middle school students, only the Ratio and Proportion, and Kinetic Energy and Potential Energy lesson modules were covered. Details of each lesson modules are included in the project website (www.flyhightu.weebly.com).

The content knowledge instrument for student participants of the summer camp consisted of 20 questions (10 questions from math content and the other 10 questions from science content). The questions on the pretest and post-test instruments were not the same, though similar. The STEM attitudes assessment instrument - a 65-item survey instrument- was used with 5-point Likert scale from strongly disagree (1) to strongly agree (5), with (3) being Neutral. Based on the factor loadings, five (5) dimensions were identified from the attitudinal survey instrument: *Mathematics Importance and Usefulness (D1)*; *Mathematics Enjoyment and Aptitude (D2)*; *Science Enjoyment and Aptitude (D3)*; *Science Importance and Usefulness (D4)*, and *Math and Science Instruction (D5)*.

Procedure

The teachers were introduced to the physics of flight and aircraft controls. They then practiced flying the flight simulator. They were also given a refresher on Excel including data manipulation and graphing. The teachers were introduced to the lesson modules that were based on the '5E' instructional model[15]. They were explained the connection between the pencil-paper activities with real life examples that were implemented as simulation missions on the flight simulator. The pedagogical approach was then modeled to the teachers by the project team using the procedures of the lesson modules. This was followed by discussion on the methodology. Teams of teachers then developed their own teaching modules as part of the PD. Each team of teachers presented the developed module for discussion and feedback with the all participants in the PD.



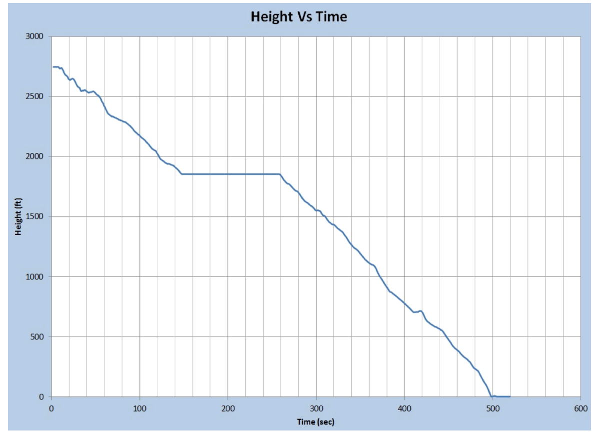


Figure 2a: Paper-Pencil Lesson Activity **Figure 2b: Flight Data**

The student participants were introduced to the physics of flight, aircraft controls, and data manipulation. They learned how to use spreadsheets (Excel) to graph, visualize and analyze the recorded data after flying a 'mission' on the flight simulator. Participating students also learned the concepts through paper-pencil exercises. Subsequently, they compared their paper-pencil results with the results using the collected data from the flight simulator mission to understand the linkages between the in-classroom learned concepts and a real-life problem. An example of teaching ratio and proportion is shown in Fig. 2. The students first solve ratio and proportion questions using paper and pencil (Fig. 2a). They then fly the landing mission. At the end of the flight, the altitude vs time data that is recorded as a text file during the flight is extracted by the students to an Excel sheet and then plotted (Fig. 2b). This data and the graph is now used to answer similar questions as the paper pencil exercises.

The teachers' attitudes towards the pedagogical approach were surveyed at the end of the PD using a survey with a 5-point Likert scale. A repeated-measures within-subject (pre-post) design was used to assess the impact of the intervention on attitudes towards STEM and content knowledge of the students.

Results

The post-PD workshop responses of the teachers to the professional development survey were analyzed to determine the effectiveness of the workshop as well as their attitudes towards the teaching methodology. Some of responses of post-PD survey are shown in Fig. 3 below.

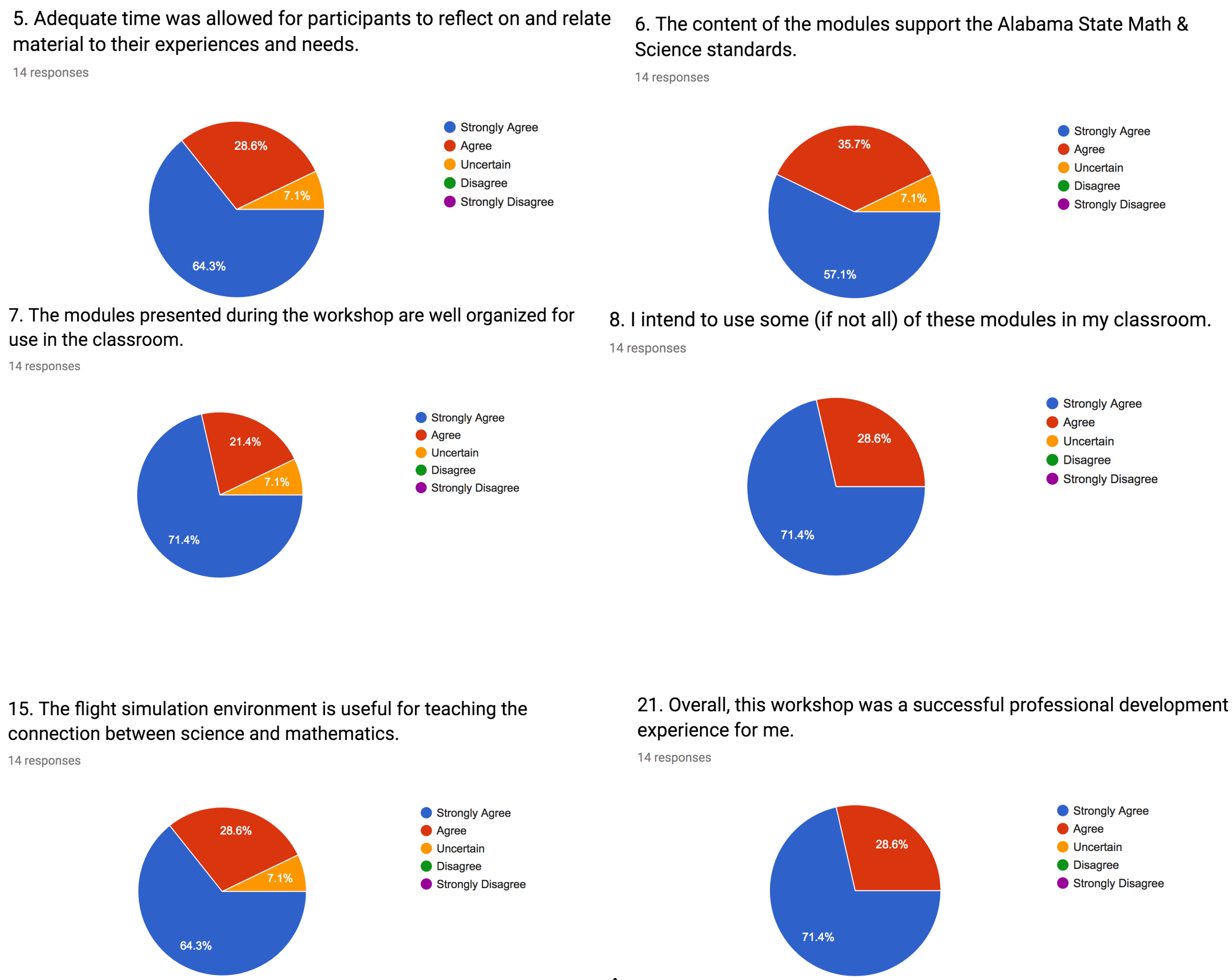


Figure 3: Responses of Teachers to the Professional Development Workshop

The subsequent paragraphs report the analysis of the student participants' data. A two-tail correlated samples t-test was done for the pre-post data. Not all questions on the attitude survey showed statistically significant ($p < 0.05$) changes in the responses. The pre-post correlated samples two-tail t-test of responses of all participants (males and females) to the questions that resulted in statistically significant change in the means at a $p < 0.05$ 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 Student Participants

The data was then analyzed to determine if gender played a role in the effectiveness of the intervention. The comparison between males and females responses to the attitudes survey pre-test and post-test questions that were significant at $p < 0.05$ are given in Table 2.

Dimensions and its elements	Means of Responses			
	Pre-test		Post-test	
	M	F	M	F
D1: Mathematics Importance and Usefulness (9 elements)				
• It is important to know math to get a good job	4.82	4.21	---	---
• Math is useful for problems of everyday life	---	---	4.27	4.79
D2: Mathematics Enjoyment and Aptitude (15 elements)				
• Sometimes I read ahead in my math book	3.09	4.00	---	---
• Sometimes I do more math problems than given in class	---	---	3.09	4.00
• It scares me to take math	---	---	2.36	1.64
• I have a good feeling towards math	---	---	3.55	4.50
• I feel uneasy when someone talks to me about math	---	---	2.82	1.86
• It makes me nervous even to think about math	---	---	2.46	1.57
D3: Science Enjoyment and Aptitude (15 elements)				
• When I hear the word science, I have a feeling of dislike	---	---	2.36	3.00
D4: Science Importance and Usefulness (9 elements)	----	----	----	----
D5: Math and Science Instruction (17 element)				
• I think using the flight simulator can help students learn math & science concepts	4.46	3.57	---	---
• Using the flight simulator is a fun way to learn math and science concepts	---	---	4.00	4.64
• I would rather be given the right answer to a science question than to work it out myself	---	---	3.00	1.93
• I have a real desire to learn math			3.64	4.43

Table 2: Pre and Post-test Analysis of Responses by Gender of Student Participants

Table 3 below shows a pre-post comparison for males and a pre-post comparison for females. The questions for which there were statistically significant differences between pre-test and post-test for each gender are reported in Table 3. The purpose of the data presented in Table 3 is to show if males and females were impacted differently by the intervention (the summer camp).

Dimensions and its elements	Means of Responses			
	Male		Female	
	Pre	Post	Pre	Post
D1: Mathematics Importance and Usefulness (9 elements)	----	----	----	----
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)				
• 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	---	---
• Science is useful for the problems of everyday life	---	---	4.07	4.57
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	---	---
• Using the flight simulator in the class is a fun way to learn math and science concepts	---	---	3.71	4.64
• I think using the flight simulator can help students learn science concepts	---	---	3.71	4.43
• I think using the flight simulator can help students learn math concepts	---	---	3.57	4.71

Table 3: Pre-Post Analysis of Responses for Male and Female Student Participants

The average percentage change in attitudes for females and males in each dimension was also compared as shown in Fig. 4 below.

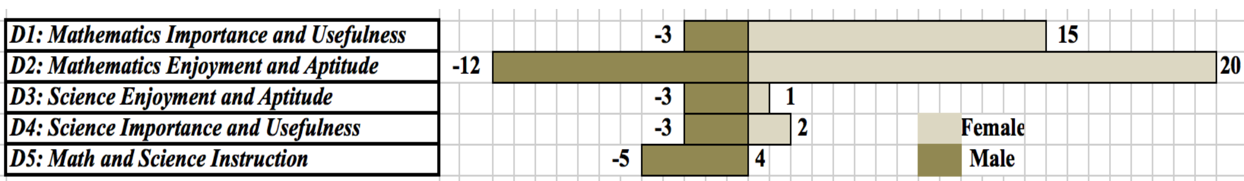


Figure 4: Pre-Post Average %Change in Each Dimension for Student Participants

The effect of the intervention on understanding of the concepts that the students learned during the camp was measured by the content assessment instrument. The pre/post-test comparison showed a statistically significant ($p < 0.05$) improvement on four questions out of the ten questions on the concept of ratio and proportion. A comparison between males and females on the pretest and post-test performance did not show any significant difference between them. The pre/post analysis of the kinetic energy and potential energy content knowledge showed no statistically significant change in the content knowledge. However, there was a statistically significant lower performance of females on the energy content as compared to males.

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 post-PD survey indicated (Fig. 3) that the teachers considered the pedagogical approach to be usable in their classrooms. It is important that teachers have buy-in into the pedagogical approach that they learn in a PD such that they can integrate the technological approach in their teaching. In this case, the teachers were involved in the process from the start. They found the lessons contents to be in alignment with the standards, and not something additional to their curriculum. They therefore indicated that they would use the learning modules in their classrooms.

The effectiveness of the intervention on the students is based on the observation of statistically significant changes in the responses to the survey questions.

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 towards the importance of mathematics (D1), aptitude towards science (D3), and the usefulness of science (D4). The gender-based data analyses provided additional information about the effectiveness of the intervention.

A comparison of the pre-intervention responses of male and female participants (Table 2) showed that there were some differences in attitudes. Of the four dimensions on which the difference was statistically significant, males ascribed higher importance to math for getting a good job (D1). However, females exhibited higher self-efficacy in math (D2) and good aptitude for science (D3). Females also indicated that the use of flight simulator in learning math and science can be helpful (D5).

A comparison of the post-intervention responses of males and females showed a higher impact of the intervention on females (Table 2). Females had a higher recognition of the usefulness of math for problems of everyday life (D1). The post-test data also indicated higher self-efficacy of female students (D2). Females felt more comfortable with talking about math, had a good feeling about it, and moved towards strongly disagreeing with being nervous about math. In all these aspects of self-efficacy, the mean post-test responses of females were statistically significantly higher than male participants (D2). However, males exhibited a higher self-efficacy towards science as compared to females (D3) on the post-test. No statistically significant difference was observed between males and females on the post-test toward science importance and usefulness (D4). As a result of the intervention, the desire to learn math and science was higher for females as compared to males (D5). Female students also indicated a higher interest in flight simulator-based learning (D5).

The analysis of the pre-post responses of male participants indicated a change in the negative direction (Table 3) towards science (D3, D4, and D5). There was no statistically significant change in attitudes towards math for males. In contrast, the female students registered statistically significant positive changes (Table 3) in good feeling towards math (D2), usefulness of science (D4) and the effectiveness of the flight simulator in learning math and science (D5). Overall, it was observed that female students showed a statistically significant positive change in attitude towards learning math and science and the use of the flight simulator.

The small sample size most probably did not provide enough statistical power. However, it was observed that in general the attitudes of females on the average were impacted positively as a result of the intervention in contrast to males (Fig. 4).

The participants showed a statistically significant improvement in their content knowledge on 40% of the ratio and proportion questions indicating the effectiveness of the intervention. The intervention did not result in a statistically significant improvement in the kinetic and potential energy component of the content. This could possibly be due to the 'word-problem' nature of the questions. No gender difference was observed in the performance on the content assessment. This indicated that the intervention had a similar impact on the content knowledge of males and females.

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. This overall result may be due to the small number of participants. However, the authors wanted to share the preliminary results of their first summer program. It was observed that even though the sample was small, the intervention with the use of a flight simulator to learn math and science has a positive impact on the female participants.

Future Work

The learning materials will be revised for the following summer camps based on the feedback of the teachers and the assessment results. Additional data will be then collected during the upcoming summer camp. It is expected that the larger sample size will increase the statistical power of the analysis. The project team will be installing the software and hardware in the local middle schools so that the teachers can start using the learning modules in their classrooms.

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