Integrating Technology in the Classroom to Engage Students

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Engaging Middle School Students in STEM using a Flight Simulation Learning Environment

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Abstract

This paper will share the design of a learning environment that uses flight simulator-based activities designed to cognitively engage middle school students. The flight simulator provides an exciting, realistic, and engaging learning experience. It allows students to recognize the linkage between the concepts and application in real-world. Lesson plans were developed for several math and physics concepts integrating the flight simulator activities. To ensure buy-in for classroom implementation, the topics of these lessons were identified in consultation with the local middle school STEM teachers. Professional development on using the pedagogical approach was then provided to teachers from the middle schools that serve primarily underrepresented populations. Middle school students experienced the learning environment as part of a summer camp to deeply understand some science and math concepts. A quasi experimental between-subjects research design was used. Pre-post content and attitude instruments were utilized to collect data for determining the effectiveness of the approach. This paper provides an updated analysis (N = 50) combining the previously reported data from the 2017 camp and the implementation results of the summer 2018 camp. Results indicated statistically significant gains in students' content knowledge and positive changes in attitudes of mainly female students towards science, technology, engineering and math.

Keywords

STEM, K-12, flight simulation, mathematics, science

Introduction

The U. S. K-12 education system is facing several challenges which are of grave concern especially in context of the U.S. technological leadership of the world. These challenges include the continued global non-competitive performance of U.S. middle school students in science and mathematics in comparison to other industrialized nations of the world. According to the Program for International Students Assessment (PISA) report of 2015, U.S. 15-year-olds placed 24th in science while students from 17 countries scored significantly higher than the U.S. students [1]. In math, the U.S. students were placed 39th which is which is significantly lower than the average performance of students from the 36-member countries of the Organization for Economic Co-operation and Development (OECD) who took part in the assessment as reported in the PISA 2015 [1]. A comparison of data from PISA scores of 2000-2015 did not indicate any significant change in the performance of U.S. students in science, while in math the score in 2015 was significantly lower ($p < 0.05$) than previous years [2]. The national achievement gap in U.S. between racial and ethnic minorities, and White students is another area of concern. The PISA 2015 data indicated that the scores in science literacy of Black and Hispanic students were significantly lower (p <

0.05) than White students [2]. There are several structural reasons such as low socio-economic status [3], and non-availability of qualified teachers for this below par performance and the achievement gap [4]-[7].

While there may be other reasons impacting performance e.g. financial, from a pedagogical perspective, the low performance of US students is due to the lack of interest in science, technology, engineering and math (STEM). One reason for this lack of interest is the unengaging learning environments as reported in the High School Survey of Student Engagement [8]. This survey which was administered to more than 42,000 high school students and covered 103 schools in 27 states, found that 66% of U.S. students were bored, citing uninteresting and irrelevant materials in the classroom. Bridgeland, Dilulio and Morrison [9] identified that the major cause (46%) of school drop-out was the uninteresting nature of the classroom. Student engagement is therefore an important element of academic success, persistence and retention. Handelsman et al. [10] determined four dimensions of student engagement at the course level being skills, participation/interaction, emotional and achievement. Fredricks et al. [11] suggested the three important dimensions of students' engagement as behavioral, emotional, and cognitive. They noted that within each dimension, there could be a wide variation of intensity. They further broke these dimensions down into multiple categories. Involvement in learning is one of the categories of the behavioral domain, which they identified as consisting of persistence, effort, concentration, asking questions, and contributing to class discussion. They considered boredom, interest, and anxiety as aspects of the emotional dimension, while learning strategies such as rehearsal, summarizing and elaboration to retain, organize and understand the material as elements of the cognitive domain.

Engaging students who are not interested in STEM is a challenge. Strategies that are grounded in theories of engagement therefore need to be devised. Active learning is one such strategy. If properly designed, active learning environments promotes engagement in all the three dimensions (behavioral, cognitive and emotional) resulting in reducing absenteeism, boosting cooperative learning skills, and improving academic performance [12]. Students are motivated to learn when they perceive that "1) they are empowered, 2) the content is useful, 3) they can be successful, 4) they are interested, and 5) they feel cared about by the instructor and/or other students" [13]. Marzano, Pickering and Heflebowen [14] noted that a pedagogical environment that elicits positive responses to questions: "a) How do I feel? b) Am I interested? c) Is it important? and d) Can I do this?" may indicate an engaged student. Such an environment leads to self-efficacy which has been defined by Bandura [15] as "how well one can execute courses of action required to deal with prospective situations". Academic achievement and self-efficacy have been empirically shown to be related [16]-[20]. Successful learning enhances an individual's self-efficacy [21]-[23].

The objective of this work is to assess an innovative active learning environment. In view of the achievement gap between White students and African-American students, the target population of the research is underrepresented middle school students from a rural county with low socio-economic status. The active learning environment was designed based on the three dimensions of engagement (behavioral, cognitive and emotional). The approach is to make the learning 'interesting' and 'relevant'. These characteristics were achieved through the use of a flight simulation software that allowed students to recognize the relevance of math and science to real life while conducting hands-on activities (collecting, analyzing and interpreting data).

Method

The active learning environment was implemented using desktop flight simulation (Fig. 1) and a large screen flight simulator that had three out-of-window views (Fig. 2). The desktop set up included a joystick with an integrated throttle. The large screen out-of-window views were generated by three ultra-short-throw LCD projectors set up in a rear projection mode. The LCD projectors were driven by three dedicated PCs which were slaved to a fourth PC that served as the master. The Wideview [24] shareware was used to slave the out-of-the-window computers to the master computer through the FSUIPC [25] shareware. The master PC also powered the instrument panel display. A commercial-off-the-shelf flight simulator seat was used for the large screen flight simulator setup. The flight control yoke and throttle were connected to the master PC and attached to the seat. The Microsoft Flight Simulator X (FSX) software was used to provide hands-on activities (missions).

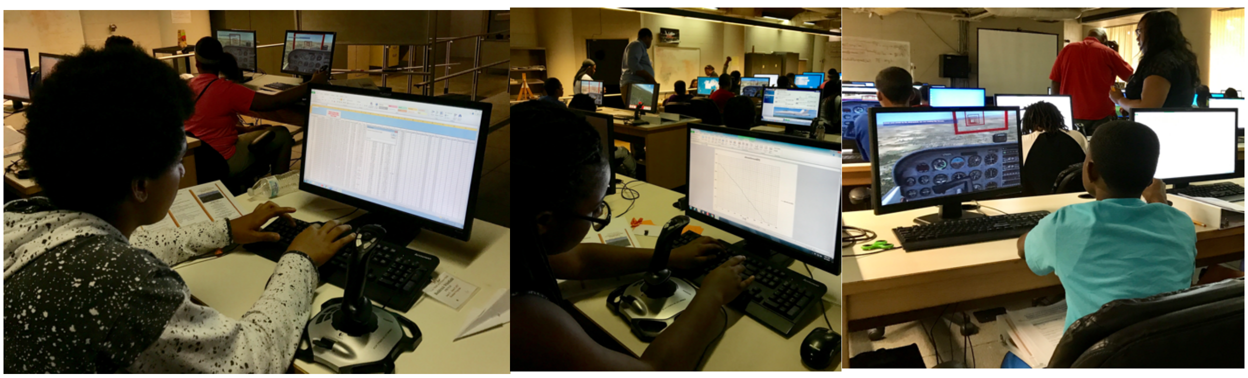

Figure 1: Students using desktop setup during summer

The FSX missions were appropriately designed to ensure that the students who were novices at flying could collect good data for analysis. For example, the flight lesson on "slope" was designed to ensure that the altitude and heading cannot be changed by the student. The only control available to the student was the throttle to accelerate or decelerate the aircraft.

Figure 2: Large screen set up

Challenging math and science concepts were identified during meetings with the middle school teachers of the local school district. Several learning modules for concepts that were amenable to flight simulator hands-on activities have been developed. Some of these modules are slope/rate of change/acceleration-deceleration, ratio and proportion, conservation of energy (potential and kinetic), and momentum. The learning modules followed the 5E approach of Engage, Explore, Explain, Extend, Evaluate [26]. Each learning module consists of (a) Basics, (b) Paper and pencil activity, (c) Flight simulator activity, (d) Data analysis and interpretation. The learning modules were designed to be completed in two 75 minutes class periods. The learning materials are accessible on the project website http://flyhightu.weebly.com.

The intervention was a one-week long summer camp. The participants of the summer camp were 7th and 8th grades students (N = 50, females = 25, males = 25). All these students were from an economically depressed rural school district, and self-identified as African-American.
The summer camp consisted of several components including learning about (a) Physics of flight, (b) Aircraft controls and instruments, (c) Flying the flight simulator, (d) Physics and math content, (d) Excel, (d) Data collection, and (e) Data analysis and interpretation. The student participants first learned about the basics of the Physics of flight which was followed by an introduction to how an aircraft is controlled in flight. They then practiced flying the flight simulator. The students then learned a math/physics concept and did pencil and paper activities. These activities were followed by flying a mission and collecting data. Next, students used Excel to plot the data to compare their results with those from the paper-pencil exercises.

A quasi-experimental within-subject research design was used to determine the impact of the intervention on the participants' attitudes towards STEM and their content knowledge. The impact of the intervention on the participants attitudes towards STEM was assessed using a 65-item survey (5-Point Likert Scale) that was administered pre and post camp. A content assessment instrument (25-items each for math and science) was also administered to the participants pre-camp and post camp. The participants were given a post camp survey as well.

Results and Discussion

The Math and Science Attitudes pre-post responses were analyzed using paired two-tail t-test at a significance level of $p < 0.05$. The 65-items of the survey loaded on four dimensions (D1, D2, D3, D4) as defined in Table-I. While most of the responses indicated a positive change in attitudes towards STEM, only few questions which are included in Table 1 registered a statistically significant change. The pre-post analysis indicated that the intervention was more effective in influencing the attitudes of the female (F) participants than the male (M) participants. The self-efficacy of the female participants increased in math (D2) and science (D3). In the pretest, the female students had a statistically lower average response as compared to the male students about the effectiveness of the flight simulator in learning math and science (D5). However, a statistically significant positive change in attitude of female students towards the use of the flight simulator was observed post intervention. There was no post-camp change in the male students' attitude towards the use of the flight simulator. The only area in which the male students registered a significant change was their recognition of the importance of math (D1).

M = 25; F =25; two-tail 't' test, p < 0.05 Dimensions and its elements with statistically significant difference	Means of Responses	
	Pre	Post
D1: Mathematics Importance and Usefulness (9 elements) • Mathematics is of great importance to a country's development	4.44 (M)	4.8 (M)

D2: Mathematics Enjoyment and Aptitude (15 elements) • Sometimes I would like to do more mathematics problems than are given in class • I feel uneasy when someone talks to me about mathematics	3.28 (F) 2.48 (F)	3.84 (F) 1.56 (F)
D3: Science Enjoyment and Aptitude (15 elements) • Science is something which I enjoy very much	3.2 (F)	3.68 (F)
D4: Science Importance and Usefulness (9 elements) • Science is something which I enjoy very much • There is little need for science in most jobs	4.16 (M); 3.80 (F) 3.36 (M); 2.76 (F)	4.04 (F)
D5: Math and Science Instruction (17 elements) • I have a real desire to learn mathematics • Use of flight sim in learning math and science	3.88 (F) 4.27 (M); 3.81 (F)	4.28 (F) 4.41 (F)

Table 1: Attitude survey responses

Analysis of the math and science content knowledge pre-post assessment of the participants indicated a positive improvement that was statistically significant ($p < 0.05$). Data for the 2018 cohort is shown in Fig. 3. The pretest average of the participants on the math content assessment was 31.8% while on the post-test the average was 59.4%. The average score of the science pretest was 33% while on the post-test the participants averaged 43.7%.

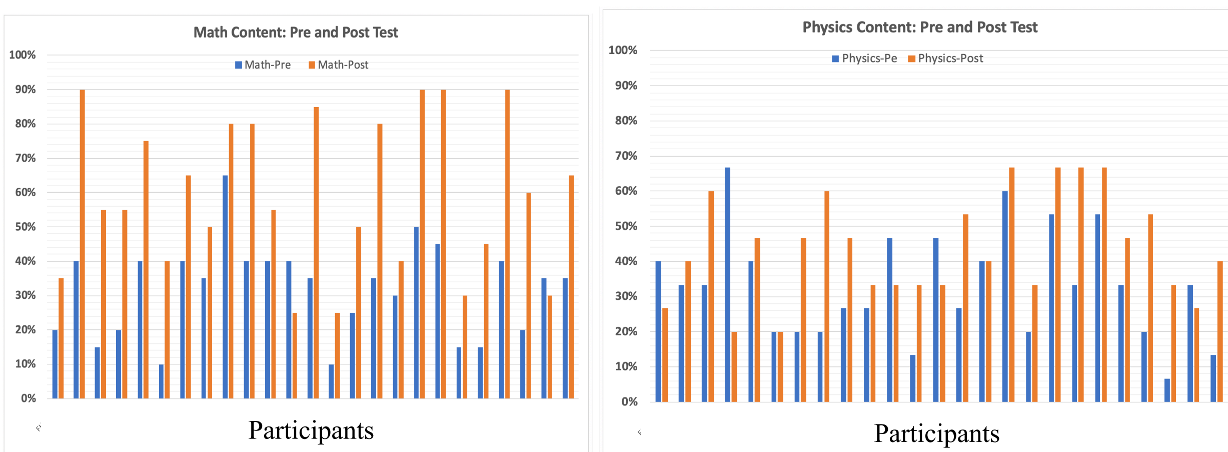

Figure 3: Performance on math and science content assessment

The participating students were also surveyed to determine their perceptions of the camp. Some typical responses are quoted below:

> "The best thing I learned at camp was learning new ways to do math, and science.
>
> We learned how to do math problems without using anything to help me.
>
> The best thing I like is flying the flight simulator and using excel to calculate our data.
>
> I like about the camp is how the teacher teach science tech engineering and math

I liked using the flight simulator and interacting with others."

Conclusions and Future Work

The results indicated that the learning environment with the active learning modules was effective in increasing the self-efficacy of the participating students, improving their attitudes towards STEM, and enhancing their content knowledge. The project team members have installed the software and a large screen set up in one local middle school (Fig. 4) and they will be installing similar one in another middle school in 2019. In addition, approximately 40 middle school math and science teachers have been imparted professional development and trained to implement the pedagogical approach in their classrooms. A third and final summer camp for students will be held in the summer of 2019. The project team is in the process of developing additional lesson modules which will be piloted during the 2019 summer camp.

Figure 4: Simulator setup in a local middle school

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