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Authentic Learning Environment with Flight Simulation Technology (Evaluation)

Dr. Chadia A. Aji, Tuskegee University

Chadia Affane Aji is a Professor in the Department of Mathematics at Tuskegee University. Dr. Aji received her Ph.D. and M.S. in Mathematics from Auburn University and a Bachelor in Chemical Engineering from Texas A&M University. Her research interests lie in the areas of numerical analysis, computational applied mathematics, complex analysis, and on improving students' learning in STEM disciplines. Dr. Aji is involved in retention activities at Tuskegee University. She helps designing strategies to assist incoming freshmen cope with first year mathematics classes. She developed teaching modules to improve students' learning in mathematics using technology.

Dr. M. Javed Khan, Tuskegee University

Dr. M. Javed Khan is Professor and Head of Aerospace Science Engineering Department at Tuskegee University. He received his Ph.D. in Aerospace Engineering from Texas A&M University, M.S. in Aeronautical Engineering from the US Air Force Institute of Technology, and B.E. in Aerospace Engineering from the PAF College of Aeronautical Engineering. He also has served as Professor and Head of Aerospace Engineering Department at the National University of Science and Technology,Pakistan. His research interests include experimental aerodynamics, aircraft design and engineering education.

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Abstract

The primary advantage of an authentic learning environment is to promote engagement with content resulting in improved academic performance and persistence. The use of technology can promote an authentic learning environment. However, rural school districts typically lack the resources for implementing technology-supported authentic learning. The research presented in this paper is based on the development and assessment of an authentic learning environment for three rural middle schools located in economically depressed counties. Flight simulation hardware and software were used to support the authentic learning of several math and science concepts and their relation to engineering. The effectiveness of the pedagogical approach was assessed using a quasi-experimental within subject research design. The intervention was a week-long professional development workshop for math and science teachers followed by a week-long summer camp for students. A total of 25 students were recruited from these middle schools. A total of 23 teachers were recruited from four school districts, three of which are rural and one is an urban school district. All students and teachers were from underrepresented groups. Data were collected using the Math and Science Teaching Efficacy Beliefs instruments for teachers, and a validated 65-item STEM attitude survey for students. A content knowledge assessment was also conducted for the students. Analyses of data from the professional development workshop and the summer camp indicated a positive impact of the teaching and learning technique. The teachers reported high self-efficacy in their ability to implement the approach in their classrooms. Assessment of students' content knowledge showed increased understanding of the concepts taught with the approach. A positive attitude towards STEM was also reported by the student participants. This research is supported by NSF Grant# 1614249.

Introduction

The science, technology, engineering and mathematics (STEM) workforce pipeline is facing multiple challenges. The first challenge is the relatively lower academic performance of US students in comparison to the other 35 countries of the Organization of Economic Cooperation and Development (OECD) as evidenced by the data of the Program for International Student Assessment (PISA). According to the 2018 assessment PISA [1] which measured the mathematics, science and reading skills of 15-year old students from almost 80 countries, the average score of US students in science was lower than six of the 36 countries OECD. The performance of US students in math literacy is even more concerning. The average score of US students in math was lower than the average math score of students from all the OECD countries. The other challenges include lower interest of US students in pursuing STEM education [2] and careers, and persistence in STEM of those students who do decide to pursue it in college [3].

One major aspect of low academic performance of students is engagement with the learning materials. In the 2016 High School Survey of Students Engagement [4], 83 percent of the respondents from the National Association of Independent Schools said that they were sometimes or often bored. The main reason quoted by them was that the learning materials were not interesting. A large percentage of the students who thought of dropping out did not see "value" in the work that they were asked to do. Thus "engagement" is an essential element of academic success. Various studies have identified the dimension of engagement to be cognitive, behavioral and emotional (or affective) [5]. The role of cognitive engagement in the learning process, and developing self-regulated learners has been reported in research literature [6]. Linnenbrink and Pintrich [7] have explored the relationship between self-efficacy, engagement and learning. Several elements of a cognitively engagement environment have been identified [8], [9]. To cognitively engage students, the learning should be "authentic", i.e. the learning should have a relationship with its application in real life. This aspect feeds off of the need of students to find relevance and utility of what is being learned [10], [11]. Additionally, the learning should be inquiry-based [8], [9], i.e. collection, analysis and interpretation of data. The learning should be collaborative [8], [9], while Blumenfeld, Kempler and Krajcik [8] consider technology as an element of a cognitively engaging environment since it can be effectively used as a hook to engage students. The positive impact of technology on engagement has been reported in several studies [12] – [14].

The primary advantage of an authentic learning environment is that it promotes engagement with the content to be learned. The result is increased self-efficacy, motivation and persistence. Improved academic performance is a result of this interaction between engagement, self-efficacy and motivation. This connection between engagement, self-efficacy, and motivation is well documented in literature. Bandura [15] defined self-efficacy as "how well one can execute courses of action required to deal with prospective situations". An empirical investigation by [16] suggested a strong influence of self-efficacy on academic performance. Classroom structure (e.g. tasks, autonomy), and the perceived importance of the work being done, which are elements of a cognitively engaging environment, were observed to impact motivation [17], [18]. Studies [19] and [20] have shown that STEM self-efficacy, enjoyment and interest are correlated with pursuing STEM careers.

Rural school districts typically lack the resources for implementing technology-supported authentic learning [21], [22]. Thus, the students of rural schools have limited experience of learning environments that cognitively engage them through technology, and consequently support higher academic achievement. The present study which is funded by the National Science Foundation developed a technology supported authentic learning environment for implementation in middle schools of local school districts of economically depressed counties with predominantly African-American students. The approach however is suitable for implementation in any middle school.

Method

Flight simulator software/hardware was used to support authentic teaching and learning of STEM concepts for middle school students from two rural school districts. The flight-simulation activities provided opportunities for students to collaborate, collect, analyze, and interpret data

which are elements of authentic learning. This pedagogy allows the students to relate the math and science concepts to engineering and real-life use.
The effectiveness of the approach was assessed using a quasi-experimental within-subject research design. The intervention was a week-long professional development workshop for teachers (Figure 1a) followed by a week-long summer camp for middle school students (Figure 1b). The teacher professional development workshop included elements of best practices [23] i.e. (a) Content focus, (b) Active learning, (c) Collaboration, (d) Use of models and modeling, (e) Coaching and expert support, (f) Feedback and reflection. The teachers learned the basics of physics of flight, aircraft flight controls and practiced flying using the flight simulator software. Teaching of the example lessons was modeled by the workshop facilitators which were based on the 5E (Engage, Explore, Explain, Extend, Evaluate), approach. The teachers were given the opportunity to work in groups and develop their own learning modules and then present/critique their work.

Figure 1a. Professional Development Participants

Figure 1b. Summer Camp Student Participants

The students participated in a one-week long day camp. They were exposed to several activities (Figure 2) in addition to the learning of specific math and science concepts and their relationship to engineering such as siting a building in the landing approach path of an airfield. They also learned the basics of aerodynamics including Bernoulli's principle, physics of flight, aircraft instruments and how they work, aircraft cockpit controls and control surfaces. These topics exposed students to aerospace engineering. They also learned how to 'fly' the desktop flight simulator. The students learned the use of Excel to manipulate and graph data that they would collect while 'flying' the missions.


Figure 2. Students Engaged in Activities

Participants

Students (N = 25) were recruited from three local middle schools which were located in counties that were rural and economically depressed. All these students were from underrepresented groups. Middle school teachers (N = 23, female = 15, male = 8) were recruited from four school districts, three of which were rural and one was an urban school district. Of these teachers, 12 were math and 11 were science teachers. All teachers were from underrepresented groups.

Materials

A PC-based off-the-shelf commercial flight simulator software, and desktop joystick/throttle were used by students to fly specially designed "missions" to collect flight data which were plotted and analyzed using Excel. Several modules with different topics such as similar triangles, potential and kinetic energy, circumference of a circle, have been developed with the incorporation of flight simulation scenarios. Each module consists of a sample lesson with basic concepts on the covered topic, paper-pencil activities and a flight simulator-based activity. Details of the modules are included in the project website (the website will be included in the final paper. This website also contains details information about the project and the implementation methodology).

Data were collected to answer the following research questions:

(a) To what extent does the pedagogical approach impact the attitudes of students towards STEM?
(b) To what extent does the pedagogical approach improve the content knowledge of the students?
(c) To what extent are teachers accepting and comfortable with the pedagogical approach?

The Science/Math Teachers Efficacy Belief Instrument (S/MTEBI) [24] was used to measure the attitudes of the participant teachers. This 25-item instrument measures the Teacher Efficacy Belief (13 items) and Teaching Outcome Expectancy (12 items) dimensions on a 5-point Likert scale (SA - strongly agree, A – agree, N – neutral, D – disagree, SD -strongly disagree). An additional 5 items were included in the questionnaire to measure the attitude towards implementing technology in the classroom. The questionnaire was administered to the teachers at the start of the workshop and then at the end of the workshop. A post-workshop questionnaire was also administered to the teachers to determine their perceptions of the professional development, and the pedagogy.

The student participants were administered a 65-item questionnaire pre-camp and post camp to measure their attitudes toward math, science and the use of flight simulator in learning. This questionnaire also has a 5-point Likert scale (SA - strongly agree, A – agree, N – neutral, D – disagree, SD -strongly disagree). A pre and post-camp math and science content assessment was also administered to the participant students. The students responded to a post-camp questionnaire with their feedback and perceptions of the summer camp.

Results and Discussion

The teachers pre-post workshop responses to the S/MTEBI were compared using paired two-tailed t-tests ($p < 0.05$) to determine the impact of the professional development. The averages of the responses of each dimension are shown in Table 1. As can be observed, while there was an increase in the means, the change was not statistically significant.

	Science + Math Teachers (df = 22)			Science Teachers (df = 10)			Math Teachers (df = 11)		
Dimension	Pre	Post	t	Pre	Post	t	Pre	Post	t
Teacher Efficacy Beliefs	4.28	4.37	0.777	4.33	4.46	1.102	4.24	4.28	0.238
Teacher Outcomes Expectancy	3.54	3.65	1.153	3.3	3.48	1.296	3.76	3.81	0.351
Integration of Technology in Teaching	3.99	4.10	0.966	3.96	4.06	0.669	4.02	4.13	0.681

Table 1: Pre-post Means of S/MTEBI Dimensions

The average of the responses to the three dimensions for the science teachers are shown in Figures 3a, 3b, 3c. In general, the movement of the mean of the responses was towards strong agreement with the statements of the teacher efficacy belief dimension (Figure 3a). Two statements in this dimension registered a statistically significant positive change. These statements are given in Table 2.

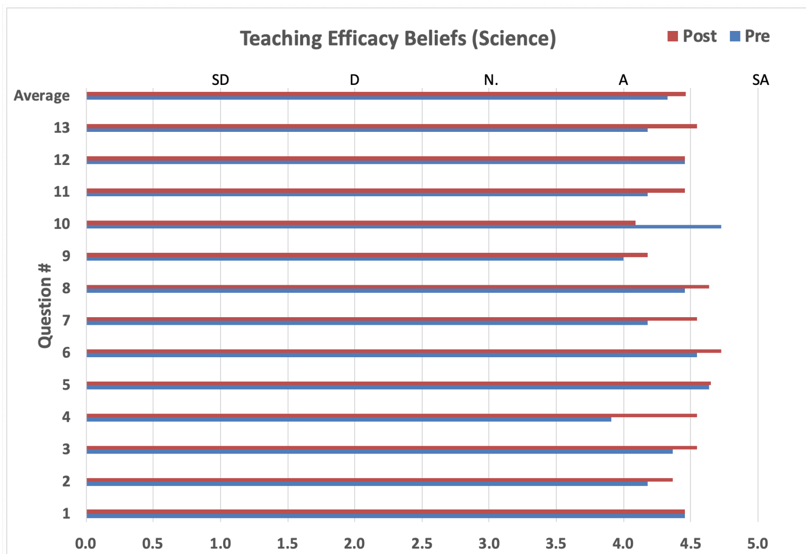

Figure 3a. Science Teachers Efficacy Beliefs

The Teacher Outcome Expectancy Belief registered statistically significant increases in several statements (Figure 3b). These statements are shown in Table 2.

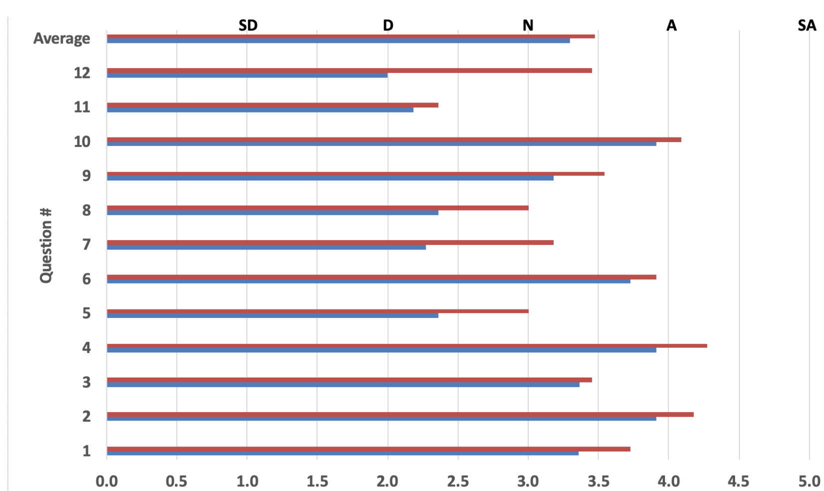

Figure 3b. Science Teachers Outcomes Expectancy

It was interesting to note that none of the five questions in the Integration of Technology in Teaching dimension registered a statistically significant change (Figure 3c). This result indicates an already positive attitude.

A number of observations were made based on the data analysis (Table 2). For the two statements of Teacher Efficacy

Belief Dimension registering a statistically significant change, the science teachers mean responses to the pretest of the STEBI were higher as compared to the math teachers mean responses to the MTEBI pretest. The pretest data indicated that the science teachers had a higher efficacy as compared to the math teacher at the start of the professional development workshop. The mean responses to several statements within both dimensions of the S/MTEBI (Efficacy Beliefs and Outcomes Expectancy) registered a statistically significant ($p < 0.05$) increase from pre-workshop to post-workshop. There were statements to which the science teachers registered significant changes; however, the math teachers did not register any significant changes. These statements are shown in Table 2.

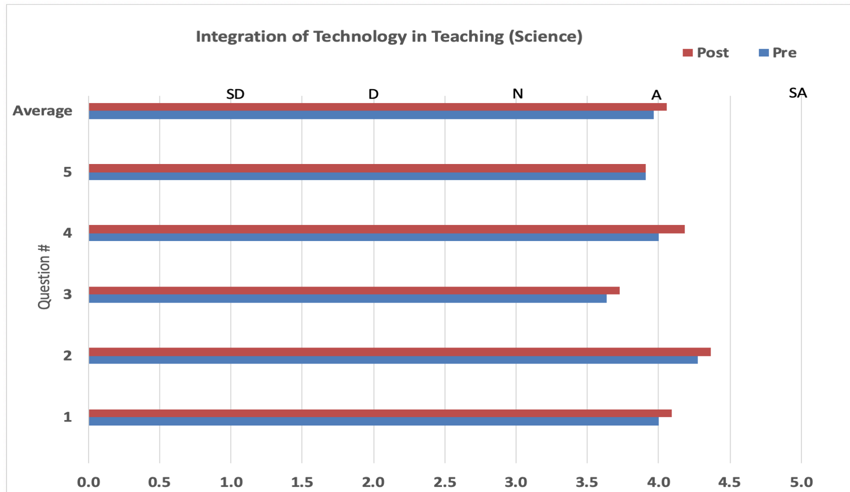

Figure 3c. Science Teachers Integration of Technology

Dimension/Item	Science and Math Teachers (df =22)			Science Teachers (df = 10)			Math Teachers (df = 11)		
	Pre	Post	t, p	Pre	Post	t, p	Pre	Post	t
Teacher Efficacy Beliefs									
I am not very effective in monitoring science/math activities. (reverse scored)	3.83	4.17	1.866	3.91	4.55*	2.283 p < .05	3.75	3.83	0.364
I do not know what to do to make students interested and like science/math. (reverse scored)	3.91	4.17	1.664	4.18	4.55*	2.39 p < 0.05	3.67	3.83	0.616
Teacher Outcomes Expectancy									
Even teachers have good science/math teaching abilities they cannot help some students (reversed scored)	2.78	3.43*	2.343 p < 0.05	2.00	3.45*	3.73 p < .005	3.50	3.52	0.321
The inadequacy of a student's science/math background can be overcome by good teaching.	3.96	4.17	2.011	3.91	4.27*	2.39 p < .05	4.00	4.08	0.561
Students' achievement in science/math is directly related to their teacher's effectiveness in science/math teaching	3.57	3.78	1.311	3.18	3.55*	2.39 p < .05	3.92	4.00	0.290
The low science/math achievement of some students cannot generally be blamed on their teachers (reverse scored)	2.78	3.05	1.298	2.36	3.00*	2.283 p < .05	3.17	3.08	0.321

Table 2: Pre-Post Mean Responses to S/MTEBI Questions (paired, two-tail, $p < .05$))

For four statements (Table 2) in the Teacher Outcomes Expectancy dimension registering a statistically significant change, the science teachers had a lower mean pretest score as compared to the math teachers. However, the science teachers registered a statistically significant increase in these four statements in the posttest, while the math teachers did not register a significant change. In general, the mean changes in the math teacher responses to the statements of the three dimensions registered a move in the positive direction. However, the changes were not statistically significant.

A post-workshop survey was administered to determine the teachers' perceptions of the efficacy of the professional development and the pedagogical approach to teach math and science concepts using the active-learning environment of a PC-based flight simulation software. The teachers' responses to the various questions are given in Table 3.

	SA	A	N	D	SD
Effectiveness of Pedagogy					
The flight simulation environment is useful for teaching the connection between science and mathematics.	59.1%	31.8%	9.1%		
I intend to use some if not all of the modules in my classroom.	45.5%	45.5%	8%		
Effectiveness of Workshop					
The instructors were effective teachers	68.2%	27.3%	4.5%		
Adequate time was allocated to the hands-on activity for developing a lesson	54.5%	40.9%	4.6%		
The workshop has provided adequate knowledge and training to use the flight simulation environment in the class room.	59.1%	31.5%	4.7%	4.7%	
Overall, this workshop was a successful professional development experience for me.	68.2%	27.3%	4.5%		

Table 3. Post-workshop survey

The pre-post responses of the students to the 65-item attitude questionnaire was analyzed using the paired two-tailed t-test ($p < 0.05$). This questionnaire measured the math/science enjoyment, math/science importance and the math/science instruction dimensions. The pre-post means of each dimension is shown in Table 4. The changes in the attitudes of the students in all dimensions were statistically significant. It was interesting to note that in the pretest, the science enjoyment dimension had the lowest mean indicating that the students coming into the camp did not consider science as enjoyable.

Dimension	Pretest		Posttest			
	μ	σ	μ	σ	t	p
Math importance (I)	3.83	0.65	4.22	0.46	4.315	< .001
Math enjoyment (II)	3.44	0.69	3.72	0.63	4.317	< .001
Science enjoyment (III)	2.96	0.62	3.45	0.65	4.729	< .0001
Science importance (IV)	3.43	0.55	4.01	0.65	6.349	< .0001
Math & Science Instruction (V)	3.35	0.41	3.91	0.46	9.84	< .0001

Table 4: Summary of Pre-Post Analysis of Students' Attitudes (df = 24)

It was noted from the data analysis (Table 4) that the dimension of the importance of mathematics had the highest mean score in the pretest, while the science enjoyment had the lowest score of the five dimensions. The posttest analysis indicated that while the mean of the responses of the science enjoyment was still the lowest, the mean of science importance dimension improved in ranking of the five dimensions. This movement of the mean of the science importance dimension indicated an impact on the students as a result of the intervention.

In each dimension, several questions registered significant changes.

Dimension I (Math Importance): Out of the nine items in this dimension, six items had statistically significant positive changes. These items are given below. All nine items registered an increase in the mean responses.

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

Dimension II (Science Importance). This dimension had seven items. While all items registered an increase in the mean, the following items registered a statistically significant increase:

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

Dimension III (Math Enjoyment). There were 14-items in this dimension. All items registered an increase in the mean responses. However, only 3 statements registered a statistically significant increase in the mean responses. These items are given below.

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

Dimension IV (Science Enjoyment). Of the 15 items in this dimension, 8 items given below registered a statistically significant improvement.

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

Dimension V (Math and Science instruction). This dimension consisted of 18 items. The increases in the mean responses to 12 items which are given below registered a statistically significant increase.

1. Solving mathematics problems is fun.
2. Most people should study some science.

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

The student participants (N = 25) of the summer camp were also administered a pre-post content test to measure their learning as a result of the interventions. This content instrument had 15 questions on the math concept (similar triangles) and science concept (the atmosphere). The data in Table 5 shows that the intervention had a statistically significant ($p < 0.05$) effect (improvement) on the content knowledge of the students.

	Pretest mean %	Posttest mean %	t	p
Science content	40	68	10.47	< 0.0001
Math content	43	70	8.56	< 0.0001

Table 5: Content assessment (df = 24)

The students were also administered a post-camp questionnaire. Some representative responses are given below in Figure 4.

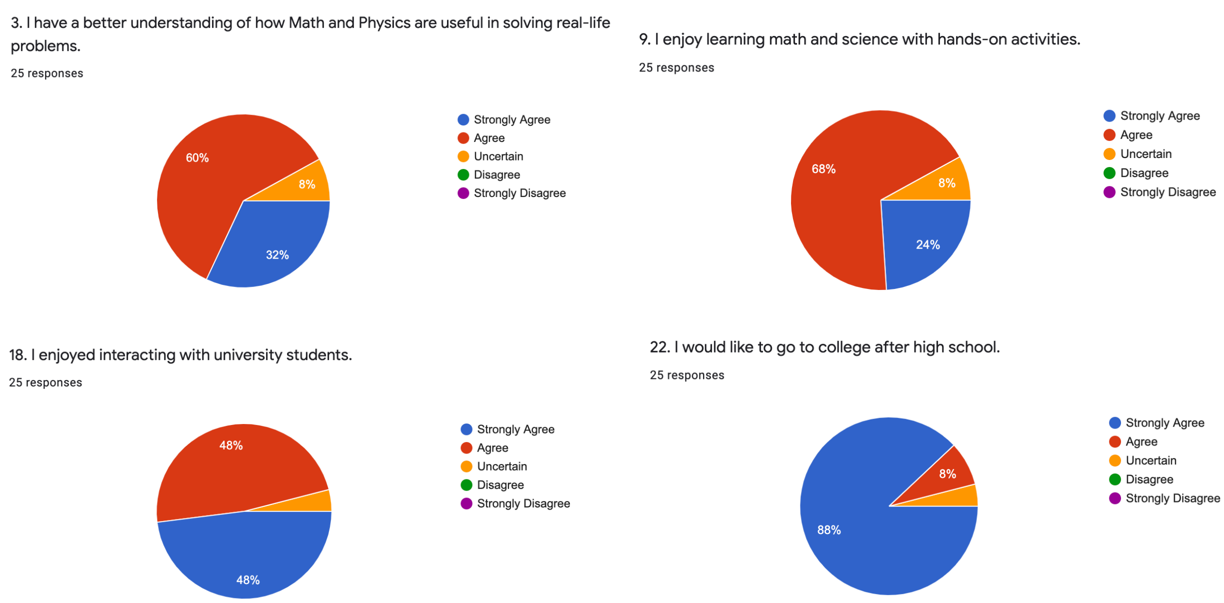

Figure 4. Post Camp Student Responses

Some comments of the students about the camp are given below:
"The best thing about the camp is that we got to interact with college students
The best thing was flight simulator.
The camp was very educational, and fun at the same time.
The summer camp was amazing and I got a chance to learn something new every day.
It was fun too come and learn math and science because when you go back to school you can already know the stuff your teacher is teaching or talking and then you can catch on."

Conclusions

Figure 5. Large Screen Flight Simulator Installation in a Middle School

The use of the flight simulation software/hardware provided an authentic learning environment in which the students were able to link math and science concepts to real world applications. Overall results of the intervention show that students enjoyed the learning with the innovative flight simulator learning-based software. Students improved their learning in the covered math and science concepts. The teachers who participated in the professional development indicated that the pedagogical approach would be effective in teaching math and science concepts to middle school students. They indicated during the professional development that the math and science teachers had the opportunity to work together to prepare collaborative math and science lessons with the integration of technology. They were motivated to work with their colleagues in their schools to prepare collaborative math and science lesson plans to demonstrate the connection to their students.

The flight simulator software/hardware has been installed in two middle school (Figure 5) and is being installed in a third middle school so that teachers can implement the pedagogical approach in their classrooms.

Acknowledgement

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