



From the Editor:

With this issue, we mark our fifth since *SAJSE* began publication in 2020. As a relative newcomer to the STEM education journal landscape, we are pleased that STEM educators continue to submit interesting manuscripts that share innovative ideas in STEM education.

We had a slight submission drop-off for this issue, but the authors who contributed have given *SAJSE* an excellent variation on STEM education subjects and projects. We are pleased to note that the author teams come from the Philippines, the U.S., and India. Each of the articles describes a unique way in which educators have implemented STEM education.

Mariefe A. Escalaw, Edd Jefferson Charles T. Ambat, Mildred M. De Leon, and Erlito B. Orlinga present research findings of a study that compared academic outcomes of tenth grade mathematics students in the Philippines who were engaged in inquiry-based STEM learning against a control group who received traditional instruction. **Thehaznna Ponnaiyan, Charlene M. Czerniak, Ahmad Javaid, Akshay Mathur, Subhrajit Majumder, Jared Oluoch, and Tod Shockey** report on an exciting NSF supported summer school project for teachers in Toledo, Ohio in which they integrate mathematics and robotics and the outcomes of interest and engagement of both students and teachers. Our third article by **Narendra D. Deshmukh, Vinita A. Shrouthy, Sneha Gogte, Sandhya A. Thakur, Nivedita Deshmukh, and Vishwanath Gogte** describes a virtual summer STEAM program for underprivileged primary children in India that engaged both students and their parents, in a completely new experience for everyone involved.

The global response to the COVID pandemic, while not over, has been to cautiously reopen schools, thus allowing more innovation and research to take place. This will undoubtedly result in more sharing of unique programs, projects, and studies, including teacher action research. We hope to be one of the beneficiaries of this upswing in on-site teaching and learning of STEM education.

We encourage STEM educators to consider submitting manuscripts that can be shared with other educators around the world, thus enriching the STEM education database and knowledge for teachers, administrators, consultants, and teacher educators. Inquiries, abstracts, and manuscript drafts may be sent to John Stiles, *SAJSE* Editor in Chief, at jsscience@yahoo.com. Author guidelines, which we strongly encourage prospective authors to read thoroughly, may be found at the following URL: www.seameo-stemed.org/journal.

As always, our hearty thanks go to the reviewers and associate editors of the *Southeast Asian Journal of STEM Education* for their selfless assistance to our mission. The next issue (Volume 4, Issue 1) will be published in January 2023.

John Stiles, Editor in Chief



The Effects of an Integrated STEM Education Approach for Online Learners in Grade 10 Mathematics: A Research Study

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Abstract

STEM education emphasizes the interconnection or integration of knowledge and skills in science, technology, engineering, and mathematics to solve problems and an approach to teaching and learning that applies and develop skills and knowledge to have solutions to problems. The integration of STEM education in teaching improves student's academic achievement in Grade 10 Mathematics. This study uses a descriptive, quasi-experimental design. The participants of the study were Grade 10 Mathematics online section at Camp Vicente Lim Integrated School. The findings showed that there was no significant difference between the two groups in the pretest, but there was a significant difference in the posttest showing that there have been significant improvements for students taught using an Integrated STEM approach. The results suggest that an integration of STEM education improves students' academic performance.

Keywords: Integrated STEM education, STEM education, mathematics, online learning.

Every country in the world strives for excellent educational standards. Aristotle (384-322 BC) claimed that education was essential and that a contented person was an educated one. According to John Dewey (1859-1952), education is not preparation for life; rather, education is life itself. No such society will flourish or progress in its original condition unless the individuals in it are educated. A developed society is made up of well-educated citizens.

Moreover, there are different disciplines being studied in the basic education. Mathematics is the science of structure, order, and relationships that arose from primitive activities of counting, measuring, and describing object forms (Yadav, 2017). It is concerned with logical thinking and quantitative computation, and its evolution has included an increasing degree of idealization and abstraction of its subject matter. Mathematics is considered to be the most difficult subject by students (Langoban, 2020). Thus, teachers are finding a way to use different strategies to increase learners' academic achievement in mathematics (Arthur et al., 2017).



STEM education is intended to inspire students to pursue these topics, as well as innovation and research, as part of their education and career pathways. The introduction of curriculum and instructional programs concentrating on science, technology, engineering, and mathematics is meant to better educate students in these areas of learning and to generate practical applications for how these teachings relate in the real world.

According to Alangari (2022), STEM education comprises long-term learning in a variety of professions. The urgent need to explore the state of, and developments in, educational research has been fuelled by international acknowledgement of the important role of STEM education (Alangari, 2022). Therefore, through STEM-based teaching activities, teachers have been successful in encouraging student creativity (Abdioglu et al., 2021). It has been proposed that creativity is a talent that can be learnt, and that creative thinking necessitates a high degree of expertise (Alangari, 2022). In the research from Carlisle and Weaver (2018), STEM education research combined with classroom instruction has a broad influence and garners attention in educational institutions. According to research, STEM education is beneficial in enhancing students' performance, including educational accomplishment, student interest, attitude, and problem-solving abilities (Saraç, 2018; Yildirim, 2016).

According to Chen and Chen (2021) it has been demonstrated that the STEM inquiry approach may predict students' originality. It examines how creativity evolves as a result of changes in education and students' critical thinking ability. The integrated STEM approach to education may help children develop good attitudes toward learning (Alangari, 2022). In the midst of the COVID-19 Pandemic, this is especially pertinent because of school reform in 21st century education. As a result, greater work is required to make a major revolutionary shift through adequate human capital development as a key to boosting any country's global competitiveness (Alangari, 2022).

On other the other hand, the integration of technology plays an important role in achieving quality and relevant 21st century digital education. Technology has often been integrated with science, mathematics, and engineering. This enables the students to have an enjoyable and meaningful learning experience. Prior research indicates that the use of ICT teaching will enhance the learning process and maximize the students' abilities in active learning (Finger & Trinidad, 2002; Jamieson-Procter et al., 2013). Additionally, the greater use of technology in education will increase educational activities and learning opportunities and as a result will lead to quality of education (Starkey et al., 2021).

In retrospect, at the World Education Forum 2015, different organizations and other international communities highlighted the importance of the United Nations Agenda 2030 for Sustainable Development Goals (UNESCO, 2017). This underlines the interconnectedness and the 21st century capabilities through ICT, enabling the great opportunities to accelerate human development and economic progress. It is also considered that ICT is one of the tools or important means to achieve Sustainable Development Goal 4 (SDG 4). One purpose of the SDG 4 is to eliminate the digital division between nations, regions, and social classes. Moreover, the



aim of SDG 4 in education is to ensure inclusion and equitable education through ICT (UNESCO, 2017).

However, the World Health Organization (WHO) declaration of the presence of SARS-Cov2 that caused the COVID-19 pandemic (Ducharme, 2020), shook the whole world and has greatly affected the facet of all human life including education. In line with health protocols as prescribed by the WHO suggested that in the opening of classes, face to face was not an option unless there would be COVID-19 vaccines available. The declaration resulted in the sudden shift of educational systems to implement distance learning that includes online learning. While this shift is indefinite, educational institutions are finding a way to deal with the situation. This study of integrated STEM-based learning in Mathematics 10 suggests that STEM-based learning that enables students to learn using actual world applications aids in developing a variety of skills, including “21st century skills,” which involve creativity and critical thinking.

One of the learning modalities in the Department of Education (DepEd) in the Philippines is the online learning modality (DepEd Order 12 s.2020). There are advantages in online learning modality compared to other modalities. In this modality the teachers have schedules of synchronous classes with the students; teaching and learning are somewhat similar as face to face but in a virtual mode. Numerous authors have suggested that an online platform provides a positive impact in e-learning (Aduba & Mayowa-Adebara, 2021; Coman et al., 2020; Quansah, 2021).

Research Questions

This study aims to assess if there is a substantial effect by teaching using an integrated STEM approach in Grade 10 Mathematics at Camp Vicente Lim Integrated School Department of Education in the Division of Calamba City, Laguna, Philippines.

Specifically, it seeks to answer the following questions:

1. What is the level of performance of the control and experimental group of students in pretest and posttest?
2. Is there a significant difference of the two groups in the pre-test?
3. Is there a significant difference of the two groups in the post-test?
4. Is there a significant difference between the pre-test and post-test scores of the control and experimental groups?

Hypotheses

The researchers were guided by the following hypotheses:

1. There is no significant difference between the two groups in the pre-test (H_0).
2. There is no significant difference of two groups in the post-test. (H_0)
3. There is no significant difference between the pre-test and post-test scores of the control and experimental groups (H_0).

Scope and Limitation of the Study

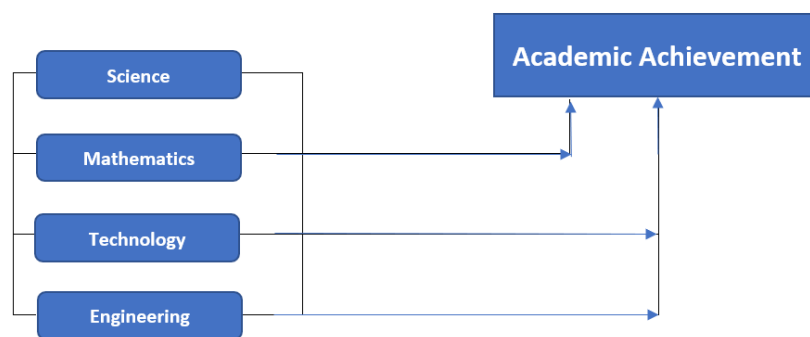
The research was conducted among Grade 10 online students of Camp Vicente Lim Integrated School for School Year (SY) 2021-2022. There were 30 students in each of two groups (The control and experimental groups). This research employed a quantitative, quasi-experimental design to get the success rate of integrating STEM Education in the new norm of the teaching and learning process during Covid-19 pandemic education. This study covers the lessons during the second quarter. Both groups took a pre-test before the start of the quarter and a post-test after the quarter was concluded. A questionnaire was constructed and administered to all students in the study.

Framework

Figure 1 shows the framework of the study. The framework displays the combinational aspect of integrated STEM education in teaching and learning in Grade 10 Mathematics for online students. This study suggests that teachers could integrate either one or two or even all four components of STEM education when teaching students. The authors are not implying that all four areas of integrated STEM must be present throughout every STEM learning event. The framework links situational learning, engineering design, scientific inquiry, and technology literacy, which is an interconnected system and a mathematical way of thinking. This pedagogy calls for a goal of using the innovation applied by the classroom teacher to significantly improve the academic achievement of the students, which is parallel to the digital education calls by the program banner of the Department of Education, “Sulong-Edukalidad” in Philippine context.

Figure 1

Conceptual Framework of the Study



Methodology

This section describes the research design, description of participants, sampling, and procedure for collecting information on the effectiveness of the integrated STEM education



approach in Grade 10 Mathematics in academic achievement of the students. This is followed by a discussion about how the data were analyzed.

Research Design

The study used quasi-experimental and descriptive design of the research. The respondents of the study are the two online sections from Grade 10 Mathematics. One group represents the control group and the second group is the experimental, or treatment group that utilized integrated STEM teaching and learning.

Participants in the Study

The respondents were limited to two sections from the Grade 10 Mathematics online section under the learning area of “Mathematics 10 of Camp Vicente Lim Integrated School, Division of Calamba City.”

There were 30 students in the control group and 30 students in the experimental group; both groups were enrolled under the online learning modality. The two groups were taught the same lessons for an academic quarter. However, the experimental group utilized the integrated STEM teaching approach. Both groups were given a pre-test and post-test for second quarter teaching and learning activities for SY 2021 – 2022.

Research Instrument

In this undertaking, both groups utilized the Department of Education (DepEd) approach, which used a “Self-Learning Module” in a soft copy form that was posted in the Learning Management System (LMS) in the teaching and learning process. However, treatment (the integrated STEM approach) was applied to the experimental group during the online classes. Additionally, the pre-test and post-test served also as research instruments in this study, which both groups utilized, as it is the DepEd approach for learning delivery amid the new normal education.

The researchers used a 50 item test for the pre-test and post-test in Grade 10 Mathematics (See Appendix). The Table of Specifications from the Department of Education (See link in References) was done before the creation of the test. The Table of Specifications contains the set competencies for the second quarter, the number of hours/meetings, topic, the number of items for which competencies are to be tested, the item distribution of the said competency, and the total number of items. Each learning episode used a Weekly Home Learning Plan and was accompanied by regular virtual meetings for actual class lessons and activities provided in Google Classroom. The participants were given the pre-test prior to lessons for second quarter and a post-test after the completion of all lessons for the given quarter. The topics for second quarter were as follows:

- Illustrate polynomials.



- Understand, describe, and interpret graphs of polynomial functions.
- Solve problems involving polynomial functions.
- Derive inductively the relations among chords, arcs, central angles, and inscribed angles.
- Prove theorems related to chords, arcs, central angles, and inscribed angles.
- Prove theorems on secants, tangents, and segments.
- Solve problems of a circle.
- Apply the distance formula to prove some geometric properties.
- Illustrate the center-radius form of the equation of a circle.
- Determine the center and radius of a circle given its equation and vice versa.
- Graph a circle and other geometric figures on the coordinate plane.

Data Gathering

After the approval of the principal to conduct the study, the teacher-researcher started the research for a quarter. The data collection was all pure online, through Google survey forms because of travel restrictions as prescribed by the health department due to COVID-19. Both pre-test and post-test scores were taken and these data were coded, calculated, and statistically processed using statistical tools employed in this study such as the mean, standard deviation, and t-test for dependent samples and t-test for independent samples

Statistical Treatment

This research used the mean and standard deviation to find the differences in the mean pre-test and post-test scores of the two groups. In addition, the dependent and independent sample tests were also used to determine the size of the difference between the dependent and independent measures. Both pre-test and post-test scores were taken, and these data were coded, calculated, and statistically processed using the mean, standard deviation, and significant difference tests. The mean and standard deviation were used to determine the level of performance of the control and experimental groups in the pre- and post-tests. The dependent sample t-test was used to determine the significant difference in the mean scores on the pre- and post-test within the same group while the independent sample t-test was utilized to analyze the mean scores of the control and experimental groups.

Research Ethics

The researcher sought permission to conduct research from the school principal by sending emails and was allowed to conduct the study. A letter was then sent to parents via Facebook Messenger to approve their child's participation in the study. Parents were guided by the purpose of the study and assurances that information collected from participants would be treated confidentially and only be used for the purpose stated in the study. The parents were also informed that they would be given a copy of the research results of the study.

Results and Discussion

This section specifies the results of data collection and analysis and report findings concerning the research questions for this study. The following are the results and the analyses done from the data (Tables 1-4).

Table 1

Performance of Students in the Pre-test and Post-test Between Two Groups

Group	N	Pre-test		Post-test	
		Mean	SD	Mean	SD
Control	30	13.67	4.89	26.93	10.53
Experimental	30	14.83	5.36	32.00	8.81

The level of performance in the pre-test of control group is 13.67 (SD=4.89) while in the post-test is 26.93 (SD=10.53). The level of performance in the pre-test of the experimental group, which utilized the STEM education approach is 14.83 (SD=5.36), while in post-test is 32.00 (SD=8.81).

Table 2

Significance Between the Two Groups in the Pre-test

Group	Mean	SD	t-value	p-value	Decision
Control	13.67	4.89	-0.87	0.195	Accept H_0
Experimental	14.83	5.36			

The result in pre-test scores between the two groups is not significantly different where the control group scores show that $M = 13.67$, $SD = 4.89$, while the experimental group scores ($M = 14.83$, $SD = 5.36$, $t = -0.87$, $p\text{-value} = .195$), are not significant at $p < 0.05$. The standard deviation is calculated as the square root of the variance by determining the deviation of each data point from the mean. The results of 4.89 and 5.36 are not too large, which means the two classes are heterogeneous, indicating that students in each class have different levels of achievement. This is indeed a good basis because the results show that the two sections included in this study are almost the same in terms of spread of scores. Tomlinson (2009) stated that the differences between students should be overcome, so the two groups were an ideal grouping for the experiment conducted by the researcher.

This result is good since the baseline data prior to implementation of treatment show that the students have similar achievement, which would be crucial for trying out the experiment using the teaching approach treatment. The data suggest that the groups are ideal for the experiment since they possess academic similarities prior to the experiment.



Table 3

Significance Between the Two Groups in the Post-test

Group	Mean	SD	t-value	p-value	Decision
Control	26.93	10.53	-1.98	0.025	Reject H_0
Experimental	32.00	8.81			

Table 3 shows that the results in differences in the post-test between the two groups had a significant difference. Based on the data analysis, the control group had a lower score (M = 26.93, SD = 10.53) than the experimental group score (M = 32.00, SD = 8.81, $t = -1.98$, $p\text{-value} = 0.025$), which is significant at $p < 0.05$.

This shows that the integrated STEM approach in teaching is effective since there is a greater result in the post-test of the experimental group compared to the control group. This result is backed by different authors and researchers such as Chen and Chen (2021), Saraç (2018), Yildirim (2016), and Alangari (2022), who have reported that this approach improves student academic achievement.

The result is also of interest because of findings by Chen and Chen's research (2021), which showed that the STEM inquiry technique to teaching and learning enable learners to gain comprehensive information while also demonstrating critical thinking and problem-solving ability. Moreover, the integrated STEM approach to teaching may help students establish positive attitudes toward learning (Alangari, 2022). Other research shows that STEM education benefits students' academic achievement, motivation, attitude, and problem-solving ability (Saraç, 2018; Yildirim, 2016). In addition, our research study likewise backed the STEM education approach in teaching and learning process in educative process of Grade 10 Mathematics.

Table 4

Significant Differences Between the Pre-test and Post-test Scores of the Control and Experimental Groups

Group	Mean	SD	t-value	p-value	Decision
<i>Pretest vs. Post-test</i>					
Control	13.67	4.89	5.60	<0.00001	Reject H_0
	26.93	10.53			
<i>Pretest vs. Post-test</i>					
Experimental	14.83	5.36	8.32	<0.00001	Reject H_0
	32.00	8.81			



In comparing the two groups, in terms of the significant difference between the pre-test and post-test in control group, the t-value is 5.60 and p-value is < 0.00001 . The result is significant at $p < .05$. For the experimental group the t-value is 8.32 and the value of p is < 0.00001 . The result is also significant at $p < 0.05$. Although both groups showed a significant difference between their pre- and post-test scores as expected, the gain shown by the experimental group, when compared to the control group is significantly greater, as seen in Table 3. The notable significant result of the experimental group was supported by different research conducted by various authors (Le et al., 2017; Ünal, 2020; Cheng et al., 2021; Cavilla, 2017; Chang, 2019, Choy et al., 2021; Liu, 2017). Thus, the results suggest that STEM-based learning educates students to a greater extent of not only science and math but also focuses on hands-on learning using real world applications to facilitate development of a variety of skills, including creativity and 21st century skills. Therefore, according to our study, STEM education is likely to benefit students' academic achievement, student engagement, attitude, and problem-solving ability (Saraç, 2018; Yildirim, 2016).

Conclusion

STEM education emphasizes the integration or interconnection of knowledge and skills in science, technology, engineering, and mathematics to address the challenges facing society and global issues that require skilled workers and knowledgeable citizens. It is an approach to teaching and learning that involves developing skills and knowledge to solve problems. In this study two branches were integrated: the application of technology and the application of mathematics concepts and ideas to solve problems in the learning of Grade 10 Mathematics. The study revealed that the level of performance of students in the pre-test between the two groups are not significant therefore the result is good since the baseline data prior to the use of the intervention or treatment suggest that the students have similar academic achievement, which was crucial for trying out the experiment in STEM education as a teaching approach in Mathematics 10. The data suggest that the groups were ideal for the experiment since they possess similarities prior to the experiment.

However, the results in the post-test between the two groups showed that there is a significant difference, which showed that there was a greater improvement in academic performance in students whose teacher utilized an integrated STEM education approach in teaching and learning.

More so, in terms of the significant difference between the pre-test and post-test in the control group, the results revealed that there is also a significant difference with the experimental group's post-test scores. However, there is a noteworthy improvement in academic performance in students whose teacher utilized the integrated STEM education approach in teaching and learning. Therefore, the findings of the study suggest that an integrated STEM education approach in teaching and learning in Mathematics 10 is effective.

Recommendation

The researchers recommend employing an integrated STEM education approach in teaching during this pandemic education and even in the post-Covid era. It is evident from the result of the study that students who utilized the integrated STEM education approach in teaching made a significantly greater improvement in their academic performance than those in the control group. This innovation should also be utilized by teachers in different learning areas, and at different grade levels. Moreover, teacher professional development should also include pedagogical seminars or Learning Action Cell (LAC) in school levels and even in the nationwide scope of the Department of Education.

In addition, the integrated STEM education approach in teaching can also be utilized by blended learning modalities. Future researchers may also use additional variables to further this research or parallel research may be done to revisit the effect of this research.

This study and its results may give insights and a readily accessible database of information on related studies in STEM education approaches in teaching in the new normal. Parallel research may be conducted to revisit the effect of this teaching approach. Furthermore, additional variables may be used or a mixed methodology may be utilized to dig deeper on the effects of integrated STEM education approaches in teaching.



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APPENDIX:
Pre- and Post-test

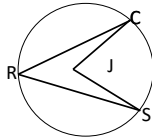
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Department of Education
Region IV-A CALABARZON Calamba City
SECOND GRADING PERIOD IN MATH10

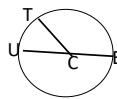
I Multiple Choice: Read the statement carefully and choose the letter that corresponds to each item.

- It is an angle whose vertex is on a circle and whose sides contain chords of the circle.
 - Central Angle
 - Intercepted Angle
 - Inscribed Angle
 - Right Angle

- In $\odot J$ on the right, what is $m\angle CRS$ if $m\angle CJS = 60^\circ$?
 - 120°
 - 90°
 - 15°
 - 30°

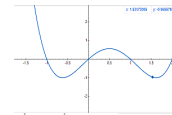


- In the circle below, what is the measure of $\angle TCE$ if UTE is a semicircle and $m\angle TCU = 70^\circ$?
 - 20°
 - 70°
 - 110°
 - 150°

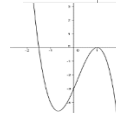


- Rewrite the polynomial function $f(x) = 2x^2 - 5x^3 + 2x^4 - 7x - 15$ in standard form.
 - $-15 - 7x + 2x^2 - 5x^3 + 2x^4$
 - $-7x - 15 + 2x^2 - 5x^3 + 2x^4$
 - $-5x^3 + 2x^4 + 2x^2 - 7x - 15$
 - $2x^4 - 5x^3 + 2x^2 - 7x - 15$

- From the choices, which polynomial function in factored form represents the given graph?
 - $y = (x+2)(x+1)(x-1)$
 - $y = (x+1)(x-1)(x-2)$
 - $y = x(x+2)(x+1)(x-1)$
 - $y = x(x+1)(x-1)(x-2)$

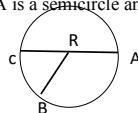


- Which polynomial function in factored form represents the given graph below?
 - $y = (2x + 3)(x - 1)^2$
 - $y = -(2x + 3)(x - 1)^2$
 - $y = (2x + 3)^2(x - 1)$
 - $y = -(2x + 3)^2(x - 1)$



- An arc of $\odot J$ measures 60° . If the radius of the circle is 36 cm, about how long the arc?
 - 6π cm
 - 12π cm
 - 18π cm
 - 36π cm

- In the circle below, determine the measure of $\angle ARB$ if CBA is a semicircle and $m\angle CRB = 102^\circ$.
 - 78°
 - 87°
 - 256°
 - 23°



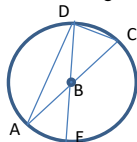
- Which of the following best describes the minor arc?
 - It measures 180°
 - It measures less than a semi-circle
 - it measures greater than a semi-circle.
 - it measures 360°

- Laine is standing on the origin of the coordinate plane. If his house is at point C (3, -6) and the church is at point A (3, 4), what is the distance between Steven's house and the church?
 - 9.2
 - 2
 - 10
 - 4

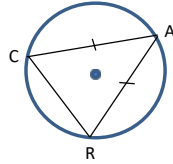
- Inscribed angles are congruent if they have common _____.
 - chord
 - diameter
 - intercepted arc
 - tangent line

12-13. REFER TO CIRCLE B.

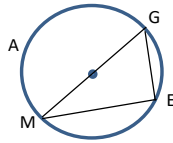
- Base on the figure shown below, which of the following statement is not true?
 - $m\angle A = m\angle C$
 - $m\angle A = m\angle D$
 - $m\angle A = m\angle E$
 - $m\angle A = m\angle B$



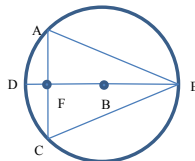
- A. $\triangle DAC$ is an acute angle.
 B. The triangle DAC intercepts the semicircle.
 C. $\angle DBA = \angle CBE$
 D. $\angle DAC = 1/2 \widehat{DC}$
13. What reason satisfies to the statement, $m\angle CAD = 1/2 m\angle CBD$?
 A. Definition of a circle
 B. Inscribed angles and central angles
 C. Semicircle of a circle
 D. Theorem of inscribed angles
14. Isosceles $\triangle CAR$ is inscribed in circle E. If $\widehat{CR} = 140^\circ$, which of the following is not true?



- A. $\widehat{CR} = \widehat{AR}$
 B. $\widehat{CA} = 55^\circ$
 C. $m\angle CAR = m\angle ARC$
 D. $\widehat{RA} = 110^\circ$
15. Which one of the statements is true about the given circle C, when $\angle GEM$ intercepts semicircle GAM?



- A. $\widehat{MG} = \widehat{ME}$
 B. $\angle GEM$ is an obtuse angle
 C. $\angle GEM$ is a right angle
 D. \widehat{GM} is perpendicular to \widehat{CD}
16. Which reason for each statement is NOT true about chord DC bisecting \widehat{AC} and passing through the center of Circle B.



- A. $m\widehat{AF} = m\widehat{CF}$; def. of Line segment bisector
 B. $m\angle AED = m\angle CED$; angle bisector
 C. $m\widehat{ADC} = 1/2 m\angle AEC$; theorem of inscribed angles
 D. $m\widehat{ADC} = m\angle AEC$; theorem of inscribed angles
17. Convert the vertex- form $(x-2)^2 + (y+1)^2 = 1$ into general equation of a circle.
 A. $x^2 + y^2 - 4x + 2y - 6 = 0$
 B. $x^2 + y^2 + 4x + 2y - 6 = 0$
 C. $x^2 + y^2 - 4x - 2y - 6 = 0$
 D. $x^2 + y^2 - 4x + 2y + 6 = 0$
18. Find the value of h to the equation $(x-h)^2 + (y-5)^2 = 9$ of a circle, passing through the point (1,2)
 A. 0 B. 1 C. 2 D. 3
19. What is the distance of two parallel lines $15x + 8y + 68 = 0$ and $15x + 8y - 51 = 0$?
 A. -3 B. 4 C. 7 D. 9
20. A circle has its center (-4,-2) and is tangent to the line $3x + 4y - 5 = 0$. What is the radius of the circle?
 A. 25 B. 5 C. 1 D. -5
21. A circle has its center (-4,-2) and is tangent to the line $3x + 4y - 5 = 0$. What is the equation of the diameter that is perpendicular in the line?
 A. $4x - 3y = 10$ B. $4x - 3y = -10$ C. $4x - 3y = -16$ D. $4x + 3y = -22$
22. Which of the following polynomial functions gives behavior of the graph that is rising to the left hand and falling to the right with zeros -1, 2 and 3?
 A. $y = -(x+1)(x-2)$ C. $y = (x-3)^2(x+1)^2(x-2)$



- B. $y = (x+4)(x-1)(x-3)$ D. $y = -(x+1)(x-2)(x-3)$
 23. How many turning points does the given function $y = -(x-5)(x-1)^2(x-2)^3$ has?
 A. 3 B. 4 C. 5 D. 6
 24. It is the line that intersects a circle at exactly two points.
 A. Tangent line B. secant line C. inscribed angle D. central angle

25. Given the unit circle below, if the measure of $\angle MAT = 48^\circ$, find the measure of $\angle MET$.

- A. 48° B. 68° C. 82° D. 96°

26. Given the figure below, find $\angle 2$, if the $m\widehat{AB} = 123^\circ$ and $m\widehat{AD} = 57^\circ$.

- A. 123° B. 75° C. 65° D. 57°

27. Which of these is a factored form of $P(x) = x^3 - 2x^2 + x$?

- A. $P(x) = (x-1)^2(x+1)$ C. $P(x) = x(x+1)^2$
 B. $P(x) = x(x-1)^2$ D. $P(x) = x(x+1)(x-1)$

28. $\overline{LM} = 5x - 15$ cm and $\overline{MN} = 3x + 13$ cm. How long is the circle's diameter?

- A. 55 cm C. 100 cm
 B. 75 cm D. 110 cm

29. The endpoints of the diameter of a circle are $(-2, -6)$ and $(8, 14)$. What is the length of the radius of the circle?

- A. $25\sqrt{5}$ B. $10\sqrt{5}$ C. $5\sqrt{5}$ D. $\sqrt{5}$

30. Which of the following is tangent to $\odot F$ as shown in the figure?

- A. \overleftrightarrow{DE}
 B. \overleftrightarrow{AG}
 C. \overleftrightarrow{BD}
 D. \overleftrightarrow{AE}

31. Quadrilateral ABCD is inscribed in a circle. Which of the following is true about the angle's measure in a quadrilateral?

- I. $m\angle A + m\angle C = 180$ II. $m\angle B + m\angle D = 180$ III. $m\angle A + m\angle C = 90$

- A. I and II B. II and III C. I and III D. I, II, and III

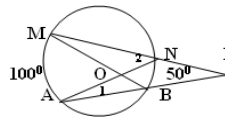
32. Mary designed a pendant. It is a regular decagon set in a circle. Suppose the opposite vertices are connected by line segments and meet at the center of the circle. Compute the measure of each angle formed at the center?

- A. 22° B. 36° C. 45° D. 135°

33. In circle O, $m\angle MA = 100^\circ$, $m\angle NB = 50^\circ$ and $m\angle MN = 95^\circ$ as shown in the

figure. Give the sum of the measure of $\angle 1$ and $\angle 2$?

- A. 25°
 B. 45°
 C. 55°
 D. 75°



34. Which of the following is **NOT** a formula for finding the distance d between the two points on the coordinate plane?

- A. $x = |x_2 - x_1|$ C. $y = |y_2 - y_1|$
 B. $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$ D. $d = \sqrt{(x_2 - y_1)^2 + (y_2 - x_1)^2}$

35. What is the distance between points $(4a, 3b)$ and $(3a, 2b)$?

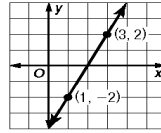
- A. $a^2 + b^2$ B. $a + b$ C. $\sqrt{a^2 + b^2}$ D. $\sqrt{a + b}$

36. The coordinates of the vertices of a triangle are $G(-4, 2)$, $O(5, -1)$, and $T(10, 8)$. What is the length of the segment joining the midpoint of GT and O ?

- A. $2\sqrt{70}$ B. $3\sqrt{70}$ C. $\sqrt{58}$ D. $\sqrt{706}$

37. What is the slope of the line shown in the graph below?

- A. 2
- B. -2
- C. $\frac{1}{2}$
- D. $-\frac{1}{2}$



38. If $MN + NO = MO$, which point is between the other two collinear points?

- A. M
- B. N
- C. O
- D. MNO

39. A radius of a circle has endpoints $(4, -1)$ and $(8, 2)$. Produce the equation that defines a circle if its center is at the fourth quadrant?

- A. $(x - 8)^2 + (y - 2)^2 = 25$
- B. $(x - 8)^2 + (y - 2)^2 = 100$
- C. $(x - 4)^2 + (y + 1)^2 = 100$
- D. $(x - 4)^2 + (y + 1)^2 = 2$

40. Using the equation $x^2 + y^2 - 4x + 10y + 13 = 0$, find the center of the circle

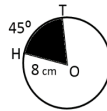
- A. $(2, 5)$
- B. $(2, -5)$
- C. $(-2, 5)$
- D. $(-2, -5)$

41. Point $C(3, 4)$ is the midpoint of \overline{AB} . If the coordinates of A are $(7, 6)$, then what is the coordinates of B ?

- A. $(-1, 2)$
- B. $(5, 5)$
- C. $(2, 1)$
- D. $(11, 8)$

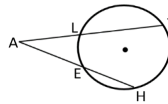
42. In $\odot O$ on the right, $m\widehat{HT} = 45^\circ$ and the length of the radius is 8 cm. Compute the area of the shaded region in terms of π ?

- A. $\pi \text{ cm}^2$
- B. $2\pi \text{ cm}^2$
- C. $4\pi \text{ cm}^2$
- D. $8\pi \text{ cm}^2$



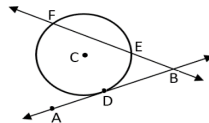
43. In the figure below, \overline{AT} and \overline{AH} are secants. If $TA = 18 \text{ cm}$, $LA = 8 \text{ cm}$, and $AE = 10 \text{ cm}$, then how long is \overline{AH} based on the given figure?

- A. 14.4 cm
- B. 20 cm
- C. 22.5 cm
- D. 24.5 cm



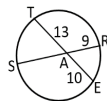
44. Line AB is tangent to $\odot C$ at D . If $m\widehat{AF} = 126^\circ$ and $m\widehat{DE} = 78^\circ$, then find $m\angle ABF$.

- A. 24°
- B. 48°
- C. 78°
- D. 122°



45. Compute the length of \overline{AS} in the figure on the right.

- A. 6.92 units
- B. $117/10$ units
- C. 14.4 units
- D. 130 units



46. How should the polynomial transformed in standard form?

- A. $f(x) = 11x^4 + 2x^3 + \frac{1}{2}x - x^2$
- B. $f(x) = -x^2 + \frac{1}{2}x + 2x^3 + 11x^4$
- C. $f(x) = 22x^4 + 4x^3 - 2x^2 + x$
- D. $f(x) = \frac{1}{2}x - x^2 + 2x^3 + 11x^4$

function $f(x) = \frac{1}{2}x - x^2 + 11x^4 + 2x^3$ be

47. A demographer predicts that the population, P , of a town t years from now can be modelled by the function $P(t) = 6t^4 - 5t^3 + 200t + 12\,000$. What will be the population of the town be two (2) years from now?

- A. 12 456
- B. 124 560
- C. 1 245 600
- D. 12 456 000

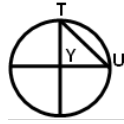
48. How long does it take for a ball to reach the height of 10 meters, when a ball is thrown in a projectile motion and represented by the function of $H(t) = t^2 - t + 30$, for which height in meters is a function of time in hours?

- A. 4 hours
- B. 5 hours
- C. 6 hours
- D. 7 hours



49. In the diagram below, which of the following

- A. $(TY + UY)^2$
- B. Square root of $(TY^2 + UY^2)$
- C. Square root of $(TY + TU)$
- D. $\frac{1}{2}(TY + UY)$



is TRUE about right triangle TYU?

50. The line segment joining $(5,-1)$ and $(-7,-5)$ is a diameter of a circle. Find the equation of a circle in vertex form.

- A. $(x-1)^2+(y-3)^2=100$
- B. $(x+1)^2+(y+3)^2=100$
- C. $(x-1)^2+(y-3)^2= 10$
- D. $(x-1)^2+(y-3)^2= 10$



Applying Project-Based Learning (PBL) to Enhance Learning in Mathematics and Career & Technology Education (CTE) Classrooms Using Robotic Smart Vehicles

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Abstract

Project-based learning has gained attention in the last decade as an effective teaching strategy that results in greater student engagement and deeper learning. This paper describes program that provided professional development (a summer institute and academic year support) to high school mathematics and career and technical education teachers. The professional development focused on a driving question related to autonomous vehicles and used robotic smart vehicles to teach concepts related to autonomous vehicles, mathematics, and career and technology education courses. The paper includes example STEM-integrated lessons that were used in the teacher professional development, links to all of the professional development program lessons (this includes two versions: one PD program that was held two weeks in-person and one that was delivered online over three weeks during COVID-19 closures), and links to selected lessons high school teachers created for their own students.

Keywords: Mathematics education, project-based learning, computational thinking, professional development

Current shortages of the workforce in STEM areas are predicted to escalate over the next few decades. In the U. S. alone, there are predictions that the economy will be short by 1.1 million STEM workers overall in 2024 (Varas, 2016). Using data from a cohort of 2009 high school freshmen, a study on occupational intentions of students and changes in intentions over the first 3 years of high school reveals that nearly half of the students who started out with an interest in STEM careers decided to pursue a non-STEM career before graduation (Holian *et al.*, 2020). According to the statistics released by the U.S. Department of Education in 2015, only 16 percent of 15-year-old high school students demonstrate interest in STEM-related careers, with women and under-represented ethnic minorities showing lower STEM career expectations (Hall & Rathburn, 2020). Additionally, women are 1.5 times more likely to leave the STEM pipeline on account of introductory math courses like Calculus I (Ellis *et al.*, 2015). Mathematics is usually found to be a less popular subject (Bragg, 2007), and students' negative attitude towards mathematics can grow with age (Mekaria *et al.*, 2016a).



Wolpert (2018) reported that one difficulty for students is a lack of a deep understanding of the mathematics, which they attribute to the memorization of mathematical rules and procedures. Paulos (1991) put this in perspective:

Imagine that 90 percent of every course in English up until college was devoted to grammar and the diagramming of sentences. Would graduates have any feeling for literature? Or let's consider a conservatory devoting around 90 percent of its effort to only practicing of the scales. Would this way be good enough for the students to develop understanding or appropriate appreciation of music? Obviously, the answer is no. In fact, this gives proper allowances for the hyperbole. This describes what frequently occurs in our mathematics classes. Mathematics is identified with a rote recitation of facts and a blind carrying out of procedures. (Paulos, 1991, p.52).

The issue of deep mathematical understanding is not solely a U.S. problem, and schools across the world are beginning to address this lack of deep conceptual understanding according to Hamilton et al. (2012).

Project-Based Learning

Project-based learning (PBL) follows an inquiry-based approach which focuses on the student's learning environment, while concentrating on disciplinary technologies, tools, and concepts to find solutions to real-world problems (Krajcik & Blumenfeld, 2006; Lee & Galindo, 2018). In contrast to conventional classroom environments, a PBL environment provides students with opportunities to develop their abilities to adapt and change methods to fit new situations, and projects integrate subject areas. Studies indicate that PBL not only enhances students' motivation to learn but also facilitates their problem-solving ability (Mekaria et al., 2016b). Typically, a *driving question* is used to frame the curriculum (Krajcik & Czerniak, 2018) and drive inquiry, which is supported by technology and collaboration (Krajcik, et al., 1999; Krajcik & Czerniak, 2018; Ruopp, 1993; Tinker, 1996). This includes extensive use of student-directed inquiry and exploration to address a complex topic or problem (Condliffe et al., 2019) and shifts responsibility for learning to students (Krajcik & Czerniak, 2018).

Students taught in traditional mathematics education environments are preoccupied by exercises, rules, and equations that need to be learned, but are of limited use in unfamiliar situations such as project tests (Hah Roh, 2003). In contrast, PBL in math results in better student learning outcomes than traditional methods (Stoica, 2015; Han et al., 2016), and raises students' interests in math (Cunská & Savicka, 2012), in addition to resulting in improved critical thinking and problem-solving skills (Mergendoller et al., 2006), and improved collaborative skills (ChanLin, 2008). Lee & Galindo (2018) provide guidance for mathematics teachers to make mathematics come alive with project-based learning, and typically such projects integrate science, technology, engineering, and mathematics as well as language arts, social studies, and art (Krajcik & Czerniak, 2018).



INITIATE Project Background

To address these issues, the project entitled INITIATE (Understanding How Integrated Computational Thinking, Engineering Design, and Mathematics Can Help Students Solve Scientific and Technical Problems in Career Technical Education) was a 3-year, NSF funded (Award # 1741784), STEM+C Partnership Program Design and Development project that partnered high school mathematics and Career Technical Education (CTE) teachers in a Midwest (U.S.) urban school district. Due to mathematics oftentimes serving as a gatekeeper for further STEM study, including technical careers, and to the strong reciprocal relationship between mathematics, computational thinking, and preparation for STEM careers, the project included teachers from these disciplines.

The INITIATE Professional Development (PD) program encompassed the following components:

- a. Preliminary technology session prior to each Summer Institute (SI)
- b. Two-three week, all day course in the summer (Summer Institute)
 - Modeling PBL lesson plans centered around robotic smart cars: multiple examples
 - Teachers develop their own project and lesson plans for implementation
 - Daily Debriefing
- c. Monthly meetings during the academic year (Professional Learning Community)
- d. Graduate Assistant support during the academic year

The INITIATE program was designed to highlight key teaching behaviors in mathematics and CTE instruction that promote reasoning, problem solving and providing students with tools and technology to experience mathematics from multiple entry points. Each year, a 2-week Summer Institute was organized at the University of Toledo (Ohio) to bring each year's cohort of high school teachers together for formal workshops and interactive lectures to provide the support necessary to develop lesson plans that incorporate the implantation of PBL and computational thinking in their classrooms using robotic smart vehicles.

Self-driving cars are beginning to gain traction as a form of Intelligent Transportation Systems, and "Look Ma, no hands!" could be the mantra of automobile drivers in the near future. In their very essence, autonomous vehicles are powered by computers through complete automation, wireless sensors, video cameras, and artificial intelligence. This technology formed the basis of the project-based learning foci of the program.

To help the teachers understand how project-based work looked, the teacher PD focused on a project-selected driving question "*How can autonomous smart vehicles affect the differently abled people of our society?*" To explore this overarching driving question, the following five sub-questions were developed in a collaborative manner with teachers that cut across multiple math and CTE courses:

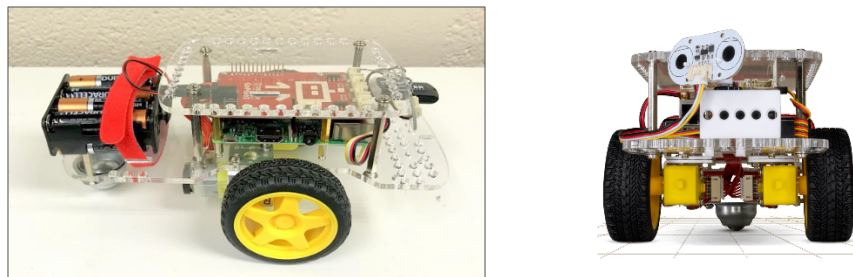
1. What are the demographics and needs of differently abled people in Toledo?
2. What routes need to be planned in Toledo?

3. How can we make smart cars safer and more convenient for the differently abled population?
4. Do smart buses meet the needs of the differently abled population?
5. How will attractions like the Toledo Zoo use smart car technology for differently abled people?

To explore these driving questions in the classroom through the lens of PBL, autonomous/robotic smart vehicle kits, GoPiGo™, (Figure 1) built using Raspberry Pi technology were purchased from Dexter Industries (www.dexterindustries.com/store/#gopigokits).

Figure 1

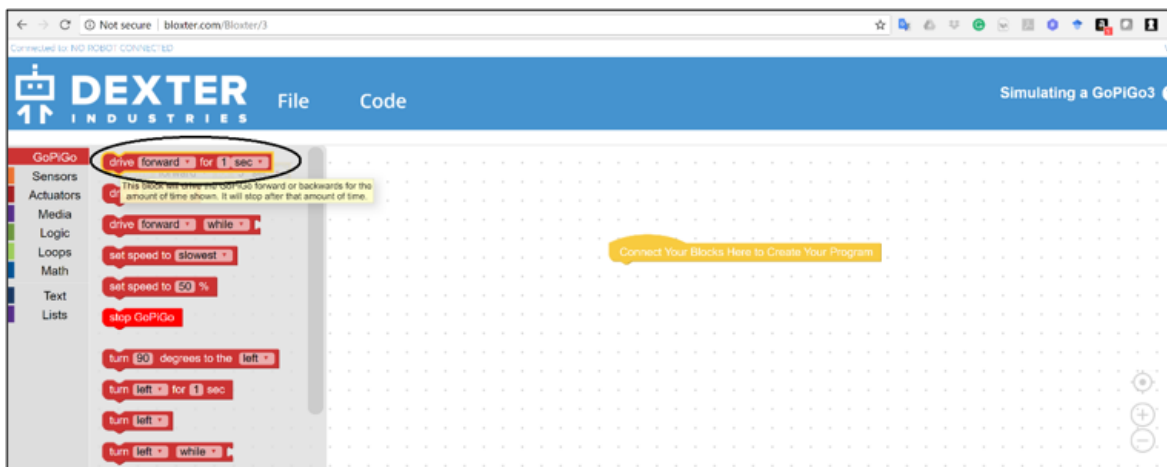
(L) Side view and (R) Front view of GoPiGo3™ robotic smart car built on Raspberry Pi technology.



The operating system for the GoPiGo™ robotic smart vehicle, DexterOS, is built-in. Programming the GoPiGo™ is achieved using Bloxter™ (Figure 2), a browser-based and user-friendly graphical programming language for learning coding with robots, also provided by Dexter Industries (<https://www.dexterindustries.com/introducing-bloxter-the-graphical-programming-language-for-learning-coding-with-robots/>).

Figure 2

Screenshot of Bloxter coding page from a web browser.





The teacher PD also involved a preliminary technology training session prior to the start of each Summer Institute to familiarize teachers with the use of a robotic smart vehicle and its inherently user-friendly Bloxter coding. The INITIATE program was designed to highlight and model key teaching behaviors in mathematics and CTE instruction that promote reasoning and problem solving as well as providing students with tools and technology to experience mathematics from multiple entry points.

A critical part of the Summer Institute included having the teachers conceptualize their own driving question for a project centered around the autonomous smart vehicles and develop their own lesson plans to be implemented in their classrooms over the course of the academic year. As modeled in the Summer Institute, they were encouraged to collaborate across mathematical and CTE topics to link lessons focused on an overarching driving question.

Beyond the Summer Institutes, we continued our engagement with teachers through the academic year. Our graduate assistants were available through email and classroom visits when teachers needed help with coding, hardware issues on the robotic smart vehicles, or assistance in the classroom when engaging their students with project developed lessons. Each month during the academic year, we held a Professional Learning Community (PLC) session at a host secondary school. During these sessions, teachers had an opportunity to stay connected with one another, get support from graduate assistants and faculty, and, importantly, give presentations on the lessons they deployed in their classrooms. In the lessons, teachers discussed the engagement of their students in PBL, content that was covered in potentially new ways, and the excitement the teachers noticed in their students. These presentations led to conversations with the larger group about successes and challenges.

INITIATE Professional Development Scope and Schedule

The PD specifically aligned to the National Council of Mathematics Teachers (NCTM) principles and standards (<https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Principles,-Standards,-and-Expectations/>). The program started each year with a Summer Institute held in the summer prior to the start of a given academic year. The sequence for activities in the Summer Institute centered around the overarching driving question and its sub-questions, as depicted in Figure 3.

Modeling PBL and CT in our Summer Institutes experienced multiple stages of evolution during the planning stage. An example is illustrated in Figures 4a and 4b, to emphasize the learning curve involved when transforming from traditional learning to PBL. This example focused on sub-question 1 within our overarching driving question – “*What are the demographics and needed of differently abled people in Toledo?*” Exploring the driving question involved using technology for data retrieval from multiple public sources, organizing and

analyzing the data (cutting across three math courses: Algebra 1, Algebra 2, and Statistics and Probability), and drawing suitable conclusions. There were two key take-away points:

- The initial PBL model in the first year started off in a top-down hierarchy in which the class engaged in data retrieval, making sense of data, and problem solving (Figure 4a). Although this encompassed many salient features of PBL, some key aspects like collaboration were missing.
- This model then evolved into splitting the class into intra- and inter-dependent groups that could work in parallel on different aspects of the project and then collaborate with each other and share data to synergistically fit the pieces of the puzzle to ultimately answer the sub-question (Figure 4b). This second iteration was much more successful in that it more closely modeled how PBL should evolve in a classroom with students being more self-directed.

Figure 3

Summer Institute 2020 timeline depicting the incorporation of multiple math and CTE courses into the project

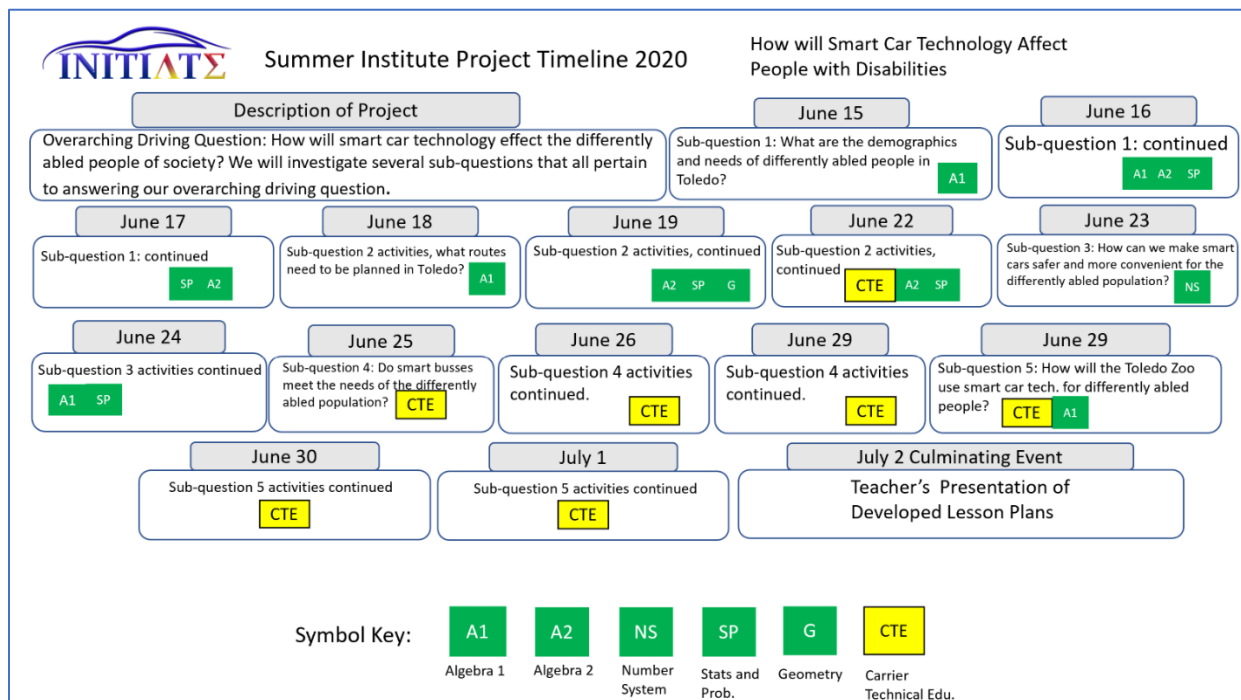


Figure 4a

Hierarchical Summer Institute 2020 timeline depicting the incorporation of multiple math and CTE courses into the project

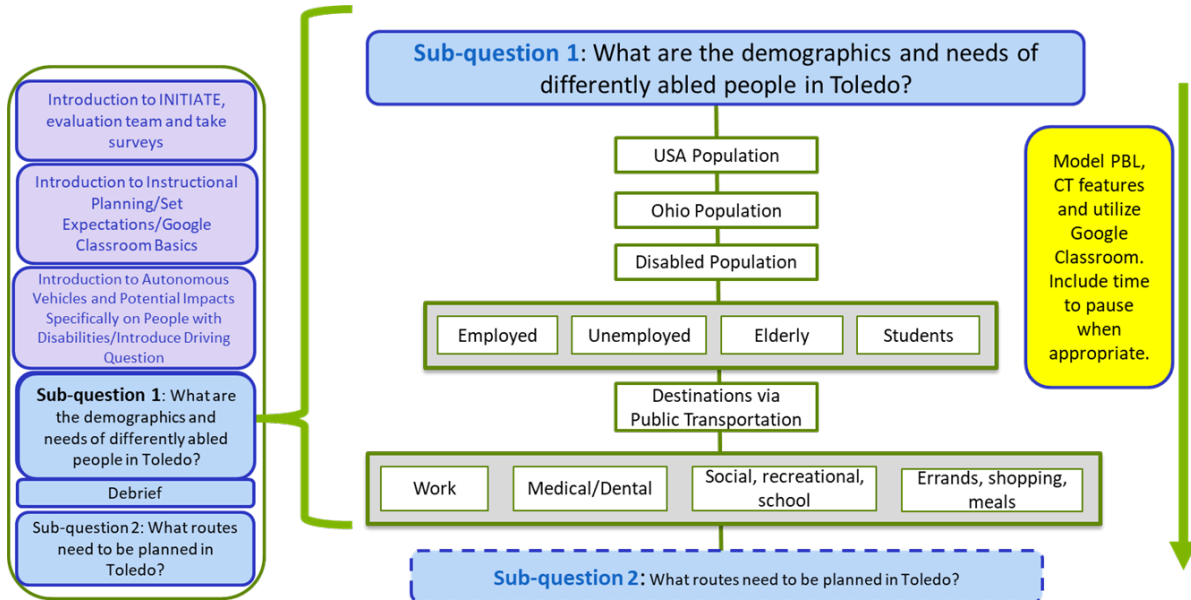
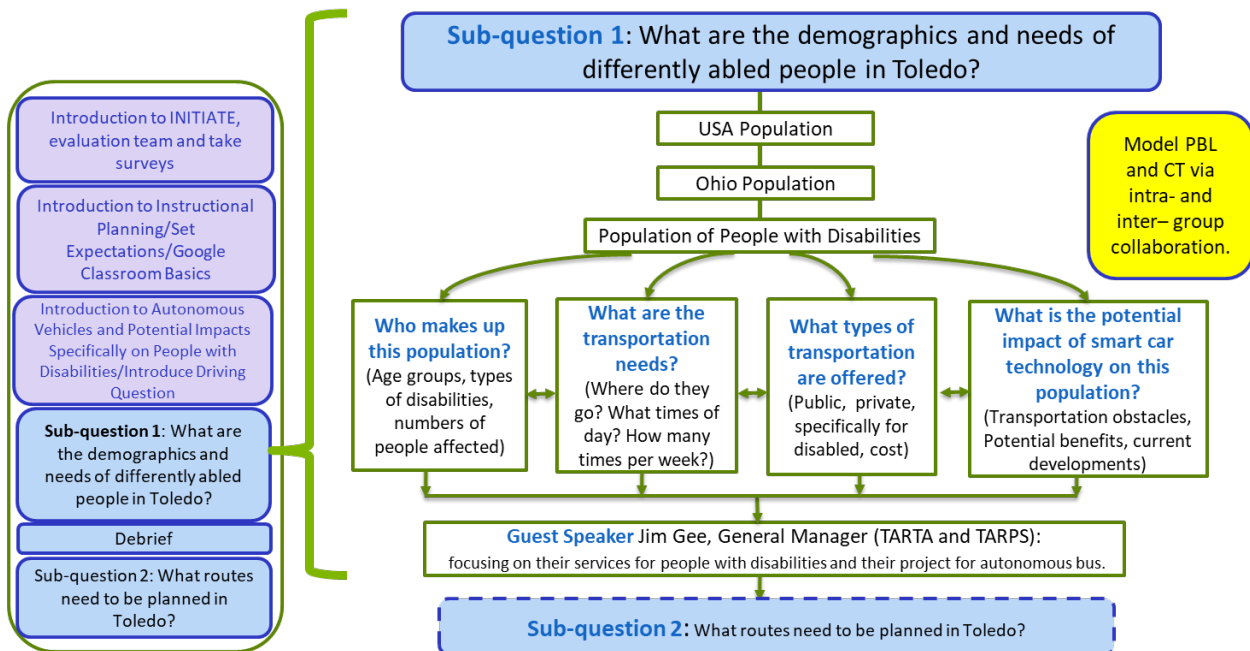


Figure 4b

Summer Institute 2020 timeline depicting the incorporation of multiple math and CTE courses into the project





In a similar fashion, the remaining sub-questions and their inherent lesson plans were collaboratively developed for the Summer Institute. The detailed schedule for a 3-week long Summer Institute, including the preliminary “technology session” to familiarize everyone with operating the autonomous smart vehicles, is depicted in the Appendix.

Sample INITIATE Professional Development Lesson Plans

For each of the sub-questions with the overarching driving question in the Summer Institute, multiple lesson plans were developed using a standard template. A sample PD lesson plan developed as part of sub-question 2 (“What routes need to be planned in Toledo?”) is provided to illustrate the application of speed, distance and time in the context of statistical methods of data analysis (averages and standard deviations) to design different routes for the autonomous smart vehicles to travel, as part of the Statistics course. The lesson plan is titled “Routes- Investigations for Designing Routes.”

In these example lessons where teachers were given two routes, they are hypothetical ones that merely use the names of real-world destinations. This was implemented for the sake of simplicity as this particular lesson plan was the first one within sub-driving question #2 and was meant to serve as an icebreaker. A subsequent lesson plan (#3- Designing a route for autonomous paratransit service) within the same sub-driving question was built on the previous ideas and students used an actual map of Toledo city to design their own set of routes from scratch thereby making it a predominantly learner-initiated problem-solving activity (see link in the next section).

Link to all INITIATE PD lesson plans

Across the lessons, we integrated STEM with social issues (accessibility for differently abled people), research, writing, and communication (Table 1). A complete set of all our PD lesson plans (two versions: a two in-person program and a three-week online program) developed for the Summer Institutes are publicly available at <https://www.utoledo.edu/research/initiate/lessonPlansPD.html>

Table 1

Lesson Plan Outline

INITIATE Lesson Plan: *Routes – Investigations for Designing Routes with Links*

Lesson plan at a glance:

Name	Routes – Investigations for Designing Routes
Course	Statistics
Grade level	9 th to 12 th

In this lesson plan...(Links)

- [Lesson Overview](#)
- [Materials and Equipment](#)



Prerequisites Speed, Distance and Time; Average and Standard Deviation

Time **Preparation:** 10 to 15 minutes
Instruction: 80 minutes

Standards Common Core:

- **S-IC:** Making Inferences and Justifying Conclusions - Make inferences and justify conclusions from experiments, observational studies and sample surveys.
- **S-ID:** Summarize, represent, and interpret data on a single count or measurement variable.

- Preparation Tasks
- The Lesson
- Learning Objectives and Standards
- Additional Information and Resources

Lesson Overview

The smart car uses many statistical methods and data analysis tools to provide a safe and comfortable ride. Along with this, the smart car needs to perform efficiently. The smart cars today use GPS modules without which they would not be able to operate. In this lesson, an experiment is to be conducted to find the total time taken by the smart car when going from point A to B using two different routes, R1 and R2, by writing two different programs to traverse each route. Once they are done writing the programs, the students need to calculate the total time taken on each route. They will perform this experiment three times and will find the average time taken in traversing each route. They also need to find the standard deviation. Based on the average time taken and the standard deviation, they infer which route should be taken to reach point B from A.

Driving Questions

Overarching Driving Question:

- How will autonomous vehicles affect the differently abled people of our society?

Lesson Specific Question:

- What routes need to be planned for these smart buses in Toledo?
 - What are some of the functionalities that your autonomous paratransit bus should have?

Materials and Equipment

For the student:

- *Required:*
 - A smart car kit [one (1) kit per three (3) students recommended].
 - An Android tablet/Chromebook connected to the smart car.
 - A cardboard with the map of the routes.
 - A stopwatch.



Preparation Tasks

<ul style="list-style-type: none"> • Check whether all tablets are working, connected to the smart car, and have sufficient battery in them. • The markings on the cardboard must be clearly visible. • To check whether the smart car is working, try to run the smart car using a single command to make the car move forward for 2 seconds. 	5 to 10 minutes
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The Lesson

Warm-up Activity: Information Gathering and Brainstorming	10 minutes
Activity 1: Speed of GoPiGo	30 minutes
Activity 2: Optimal Route	30 minutes
Wrap-up: Conclusions and Inferences	10 minutes

Warm-up Activity: Information Gathering and Brainstorming (20 minutes)

Activity Overview: In this activity, the lesson is introduced and useful information is provided about the activities that follow.

Activity:

Demonstrate how Google maps can find the route from Bowsher High School to Franklin Park Mall using the tablet.

OR

A short video on “How Google Maps find the best route for you”

(<https://www.youtube.com/watch?v=hxl1SmcDBpk>) (Google Incorporation, 2016)

Google the techniques used by Google Maps to determine the best route. Answer the following questions:

1. Do these techniques involve Math in any way? If yes, then what topics do they think are involved in the computation? If not, then how do they do it?
2. What factors do you think are considered while calculating the quickest path?

Conclusion:

Google/Apple collected all the available road data, including speed limits, traffic lights, drawbridges, etc., and then use statistical analysis tools (formulas for calculating average, standard deviation, etc.) to find Estimated Time of Arrival (ETA).



Teaching Tips:

The teacher can use an online discussion board to host these questions where students can actively discuss the warm-up questions with the teacher and peers. The teacher can act as a moderator so that the students can stay on the discussion.

Activity 1: Speed of GoPiGo (30 minutes)

Problem Statement: Find out the average speed of GoPiGo through experiments.

- Run the smart car for 2, 3, 4, 5, 6, 7, 8, 9, and 10 seconds.
- Consider the Time and Distance covered and complete a table as shown below.
- Find the Speed for each pair of values.
- Then take the average of all values of speed and find the average speed.

Time (s)	2	3	4	5	6	7	8	9	10
Distance (inch)									
Speed (inch/s)									

Section 2: Gathering Data (45 minutes)

Students can be given separate cars. They will run the smart cars for the given times. For each run, they will measure the distance (by measuring tape) covered by the smart car. The Distance is then recorded into the table. The speed for each time is calculated using the following formula:

$$\text{Speed} = \text{Distance}/\text{Time}.$$

Section 6: Analyzing the Solution (10 minutes)

An average of all the values of speed is the actual speed of the GoPiGo.

Teaching Tips:

- Students can record their experiments in a video and send to the teacher.
- The teacher can use an online portal such as Google Classroom (Google Incorporation, 2018), Blackboard, etc. to create a questionnaire, and the students can submit their answers there.

Activity 1: Optimal Route (30 mins)

Problem Statement: Find the fastest route from Franklin Park Mall to Toledo Zoo, given there are two routes, R1 and R2. Start from Franklin Park Mall. The speed limit is given in percentages, while the distance on each road is given in inches.

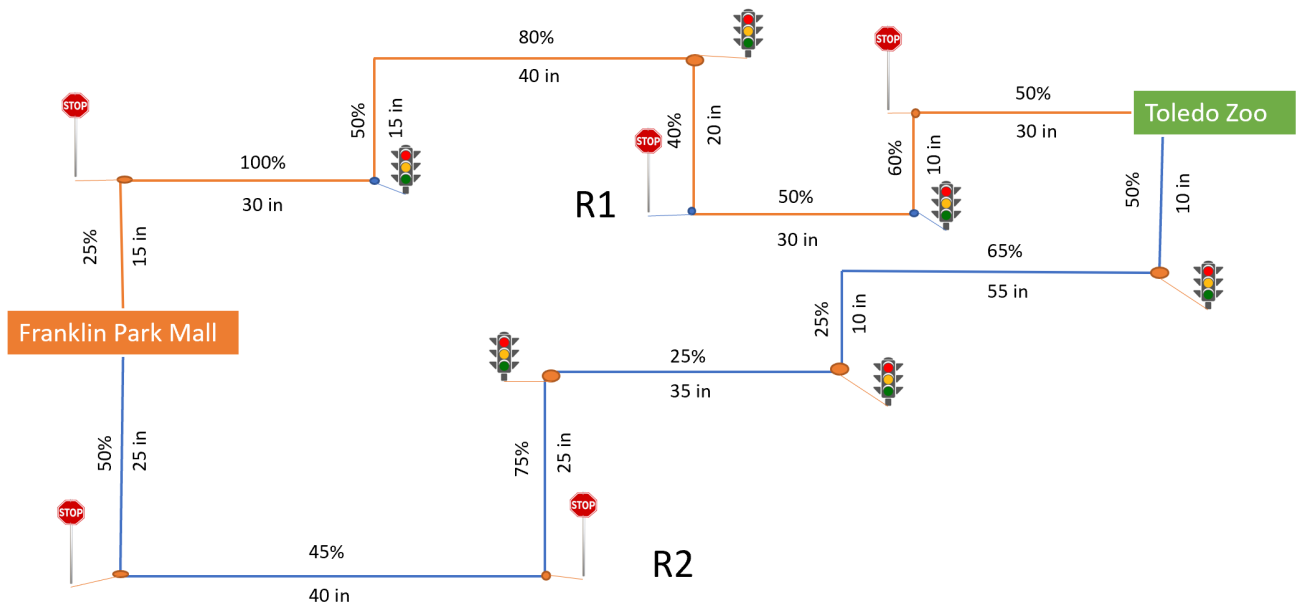
1) Represent the data in the diagram in the form of separate tables for both the routes R1 and R2 (Table 2).

The table must contain:

- given information and constraints (speed limits and distance on each road),
- time taken at stop sign is (3 seconds),
- time taken at traffic light is (6 seconds),
- Calculated information (total time taken).

2) Based on the Map (below) displayed to them they will have to devise an algorithm to traverse the route (OPTIONAL)

3) Program the GoPiGo smart car. (OPTIONAL)



Base route from Franklin Park mall to the Toledo Zoo.

Table 2

Suggested data entry table template with preliminary sample data

Route R1			Route R2		
Speed(%)	Distance(in)	Time taken (s)	Speed(%)	Distance(in)	Time taken (s)
25	15		50	25	
Stop Sign		3	Stop Sign		3
100	30		45	40	
Traffic Light		6	Stop Sign		3
		\sum time taken			\sum time taken

Solution

1) Filling out the Table (15 minutes)

- In the *Speed (%)* column enter the percentage speeds of each route.
- In the *Distance (in)* column enter the distances given for each path.
- Use the average speed of GoPiGo that you calculated the previous Activity to be the maximum speed of the GoPiGo here. The percentage values can now be converted to *in/s* for all speed percentages.
- Use the Speed-Distance-Time formula to calculate the time for each path on both the routes. Here, the total time taken is calculated using the following formula:

$$T_R = \sum \frac{Distance_i}{Speed_i} + No. of stop signs \times 3 + No. of Traffic Lights \times 5$$

Where, T_R is the time taken by a specific route R.

- Sum up the time taken on each path for both routes. The one with lesser value is the quicker route.



2) Devising an Algorithm (15 minutes)

Divide the class into 2 groups. one group will traverse R1, while the other will traverse R2
Use the following information to devise the algorithm.

There are three rules for devising this algorithm.

Sample rules:

- Travel the route R1 and R2, as seen in Figure I, following the map precisely.
- At a stop sign, stop for 3 seconds and then move again.
- At a traffic signal, stop for 5 seconds and then move.

Use Google Docs to record your devised algorithms.

Teaching Tips:

- For students good in algorithm design, the teacher can ask those students to devise an algorithm that can traverse the path or give an idea on how this functionality can be achieved.

3) Running the Program (45 minutes)

The algorithm devised in Activity 1 is to be converted into a working program on Bloxter (Dexter Industries, 2016). The program is to be written on the bloxter interface opened on a tablet.

- Open the bloxter interface on the tablet. This interface comes up when the smart car is connected to the tablet.
- Use the appropriate command blocks and change the values as per the algorithm and fix them one after the other to complete the algorithm. For example, Figure II shows how the blocks need to be connected to each other. This is the program to traverse R1.
- After writing the program, run the program once or twice to check if it is working properly.
- Now place 2 cars at Franklin Park Mall, one programmed to traverse R1 and the other programmed to traverse R2. The two cars can be run separately, and time can be recorded using a stopwatch.

Teaching Tips:

- In case of an online lesson plan, the teacher can skip parts 2 and 3.
- The teacher may give one GoPiGo to some students and ask them to video record their parts 2 and 3 and send it.
- For students good in algorithm design, the teacher can ask those students to devise an algorithm that can traverse the path or give an idea on how this functionality can be achieved.



Wrap-up: Conclusions and Inferences (10 minutes)

Activity:

The following questions can be asked for the wrap-up.

- Which route came out to be the best based on the experiment and the statistical analysis? Were there any differences in the results of the two activities?
- Do you think that what we designed today is the most efficient way of designing an optimal route finder? Can you think of a way to make this process a little dynamic?
- What did we learn in this lesson?

There are a lot of different ways to make the process more dynamic. Like taking input parameters from a database and then finding the best route, instead of programming the car to follow just a specific route.

Assessment:

Collect students' reflections. Assess for thoughtful, complete responses and experimental understanding. The students' interest in STEM.

Learning Objectives and Standards

Learning Objectives	Standards
LO1: Analyze a problem and suggest possible solutions.	<i>Computer Science</i> <u>CSTA L1:6.CT.6:</u> Understand the connections between computer science and other fields. <u>CCSS.MATH.PRACTICE.MP1:</u> Make sense of problems and persevere in solving them.
LO2: Identify which route took the minimum time.	<i>Common Core:</i> <ul style="list-style-type: none"> • S-IC: Making Inferences and Justifying Conclusions - Make inferences and justify conclusions from experiments, observational studies and sample surveys. • S-ID: Summarize, represent, and interpret data on a single count or measurement variable.
LO3: Verbalize a plan (an algorithm) for the whole process.	
LO4: Code the smart car to run as per the requirement in the question.	
LO5: See the mathematics behind everyday things.	
LO6: Make inferences and justify conclusions based on the observations made both by numerical analysis and experimentation.	



Additional Information and Resources

Project-based Learning Features

Feature	Where does this occur in the lesson?
Driving Question	Here our driving question is what are some of the functionalities that your autonomous paratransit bus should have? The autonomous bus should be able to find the quickest route to reach its destination and should be able to answer whether the passenger will reach on time.
Making Sense of Data	In all the activities we are collecting analytical and experimental data and trying to come up with a conclusion based on it.
Investigation & Problem Solving	Here the students are investigating the quickest route taken and the various technologies involved in finding the quickest route to reach from one place to the other
Technology Incorporation	The data are stored in Google sheets, and most of the information presented is published on Google Classroom. They are also using a smart car prototype to do the experiments.
Collaborative Opportunities	In the Activities designed, the people involved in the lesson are working in groups. They share their ideas and knowledge with each other, leading to Collaborative Learning Opportunities. They are also sharing their results and other observations in Google Classroom where they can see the results of others and learn as a group.
Assessment techniques	Assessment is done on whether the program is achieving the desired functionality, the efficiency of the program, the results obtained, and the conclusions are drawn based on the experiments conducted.

Computational Thinking Concepts

Concept	Where does this occur in the lesson?
Algorithm Design	In this lesson, all the activities require the use of a computer program for which an algorithm is necessary. In all the activities, we are developing algorithms to make the car achieve a certain functionality.
Pattern recognition	To follow the routes precisely, a pattern is observed in Activity 2.
Decomposition	In Activity 2, two programs had to be written. So, the whole problem was first decomposed into 2 parts, one being R1 and the other being R2. And further decomposing each route into separate paths. In Activity 3 and 4, the different scenarios need to be programmed separately by decomposing the problem.



Administrative Details

Contact info:	www.utoledo.edu/research/initiate
Sources:	Dexter Industries. (2016). <i>Bloxter</i> . www.bloxter.com Google Incorporation. (2016). <i>How Google Maps find the best route for you</i> . https://www.youtube.com/watch?v=hxl1SmcDBpk Google Incorporation. (2018). <i>Google Classroom</i> . classroom.google.com
Date Written:	04/20/2021
Template adapted from:	https://edu.google.com/resources/programs/exploring-computational-thinking/

Classroom Teacher's Lessons

As noted earlier, the Summer Institute provided opportunity for the teacher cohorts to develop their own STEM-integrated PBL driving question and lesson plans that could be implemented in their high school classrooms over the course of the academic year. This involved multiple math courses (Algebra 1, Algebra 2, functions and Trigonometry, and Statistics) and CTE courses (Robotics, Manufacturing Technology, and Design Architecture).

Link to teachers' lesson plans

Samples of teachers' lesson plans developed during the Summer Institute are available at: <https://www.utoledo.edu/research/initiate/lessonPlansTeachers.html>

Conclusion

This article describes a teacher PD program and presents lessons created for the PD as well as lessons teachers created for their own classrooms. In the fourth year of the project, we followed up with the teachers from all three cohorts and found most were still using the project-based approach in their classrooms. Some teachers from cohorts 1 and 2 requested extra resources, so we offered extra car kits, Chromebooks, and accessories so they could continue the work in their classrooms.

As this is not a research paper, we do not present research methodology, data tables, or detailed research information presented elsewhere. However, we summarize some findings to demonstrate the effectiveness of the project on teacher outcomes.



Below we present a few quotes from teachers (Shockey & Czerniak, 2021a, b), that illustrate their reactions to the project-based work in their classrooms and the level of student engagement:

- “Students are really engaged.”
- “Couple girls say, I love coding.” For this teacher this was very meaningful that her female students felt “it’s not that hard” and they were interested to learn more.
- “This student actually, usually doesn’t do anything at all, but everybody get involved, everybody get on the floor and measure;” “They are very excited;” After this was over “yeah, they go back to not doing anything.”
- “I wish I could do more of it, I wish there were less of the math that we do teach and more of the let’s go investigate this kind of stuff and see what’s out there.”
- “He worked by himself, which I was really surprised because I’ve known him since third grade...to see him build his confidence was really awesome.”
- “Graphing linear equations is still not covered until chapter three, and I was amazed that after I did two examples on the board that students were ready to get into GeoGebra, using their Chromebook (laptops), and were engaged 100% in technology” (Note: <https://www.geogebra.org> –Ed.)

Quantitative research presented elsewhere (Acumen, 2021) demonstrated positive outcomes on teaching:

- Pre and post observations of classroom teaching using the Electronic Quality of Inquiry Protocol (EQUIP) (Marshall, Smart, & Horton, 2010), which measures factors associated with inquiry instruction, found prior to participation in the INITIATE Summer Institute, teachers in general displayed inquiry-based instruction at the “Developing” to “Proficient” Inquiry levels with the Instructional factor showing the greatest degree of proficiency. When the teachers were observed again after their participation in the SI, there were more occurrences of “Exemplary” ratings across each of the four factors as well as improvements in both the mode and median scores. Overall, the teachers improved the most on the Assessment and Curriculum factors; however, there was more room for gain on these factors based upon pre-Institute scores.
- The median rating showed an increase in the post-Institute classroom observations on the “Instructional Strategies,” the “Order of Instruction,” and the “Teacher Role,” indicators. For “Instructional Strategies,” teachers moved from primarily lecturing to cover content to using student-led investigations to promote strong conceptual understanding. Regarding “Order of Instruction,” teachers encouraged and expected students to explain concepts rather just the teacher explaining everything. Finally, teachers moved away from being the center of the lesson to acting more like a facilitator for students to learn in their own way.
- The teachers showed overall improvement on the “Complexity of Questions,” “Questioning Ecology,” and “Classroom Interactions” indicators, moving from the Developing Inquiry category level to the Proficient Inquiry level on each scale. These suggest that teachers had increased success in engaging students in more open-ended discussions and did a better job of challenging students to explain and justify their

answers. Combined, these three indicators reflected that teachers had increased success in engaging students in more open-ended discussions and did a better job of challenging students to explain and justify their answers.

- Teachers showed increases on all indicators on the post observations indicating that they used assessment to enhance critical thinking by encouraging students to reflect on their learning at an understanding or authentic level. During post-observations teachers also solicited information to assess student understanding and took the next steps of using that information to adjust the instruction.
- While teachers improved on all indicators, the most dramatic gains were in “Learner Centrality” and “Organizing and Recording Information.” The increase in “Learner Centrality” suggests that teachers became more flexible in allowing individual students to explore and learn at their own pace as well as design and carry out their own investigations. The “Organizing” indicator reflects that teachers gave students more independence in how they organized and recorded their data and findings (as opposed to prescribing a set way). The result is a more experiential learning experience for the students.
- Measures of teacher computational thinking demonstrated statistically significant increases after the program.



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graduate courses across all four years of the chemical engineering program, incorporating Project-Based-Learning (PBL) and flipped-classroom ideologies into his courses. His research interests include classroom pedagogy in high school and university environments, advancements in biofuel technology, material properties in food and pharmaceutical formulations, and supply-chain analysis in lean manufacturing. He has also served as the curriculum director for INITIATE. Professor Ponnaiyan is a member of the American Institute of Chemical Engineers (AIChE), the American Society for Engineering Education (ASEE), and Omega Chi Epsilon (OXE) honor society. He received the ASEE Chemical Engineering Faculty Summer School Poster Award for outstanding teaching in 2017 and received the 2022 Outstanding Teacher award from the College of Engineering at the University of Toledo.

See other author bios on the following pages.



Charlene M. Czerniak is a professor emerita at The University of Toledo from the department of Curriculum and Instruction and now works as a Research Professor in the College of Engineering. She received her undergraduate degree from The University of Toledo, Master's degree from Bowling Green State University, and Ph.D. in science education from The Ohio State University. She was previously an elementary teacher in Bowling Green, OH. Dr. Czerniak has authored and co-authored over 65 professional articles and book chapters and is co-author of a textbook on project-based science teaching. She also has illustrated 12 children's science education books. Professor Czerniak has been an author and director of numerous grant funded projects of over \$35 million that targeted professional development of science and mathematics teachers. She has made frequent presentations at national and regional conferences that focus on her research interests on teachers' beliefs about teaching science, professional development for early childhood, elementary, and middle grades teachers; science education reform; and school improvement. She is an active member in, and served on committees for, the Association for Science Teacher Education (ASTE), the National Association of Research in Science Teaching (NARST), the School Science and Mathematics Association (SSMA), and the National Science Teachers Association (NSTA) and reviews manuscripts for the journals associated with these organizations. She also served as editor of the *Journal of Science Teacher Education*. Dr. Czerniak served as President of SSMA for two years, and as the President of NARST from 2008-2009. She received the 2008 Distinguished Alumni Award for Service from The University of Toledo Judith Herb College of Education and the 2008 Research Award from the Judith Herb College of Education. In 2010, she received the George Mallinson Distinguished Service Award from the School Science and Mathematics Association, and in 2012, she was named Distinguished University Professor at The University of Toledo.



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Akshay Mathur received his B.Tech (Hons.) degree in Computer Science and Engineering from Dr. A.P.J. Abdul Kalam Technical University, India. He is currently pursuing his Ph.D. in Computer Science at the University of Toledo. His primary area of research is cyber security and Android security using Machine Learning techniques and has published seven papers during his Ph.D. studies. He has also worked on improving high school education methodologies by incorporating Project-based Learning in their current curriculum. His research interests lie in Machine Learning, Software Development, and Curriculum Design.



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Jared Oluoch is an Associate Professor of Computer Science and Engineering Technology (CSET) at the University of Toledo, Ohio. He received his Ph.D. in Computer Science and Informatics from Oakland University in Rochester, Michigan. Dr. Oluoch's research interests span five broad areas: 1) Object-oriented programming for machine learning algorithms, 2) Reputation management and security of Connected and Autonomous Vehicles (CAVs), 3) Cyber Security, 4) Localization algorithms for Wireless Sensor Networks (WSNs), and 5) Engineering education. He has secured external research funding of over \$2,000,000 from NSF as the Principal Investigator. Dr. Oluoch has published in peer-reviewed conferences and journals as a primary author or co-author in his areas of research. He has advised and currently advises several masters and doctoral students in Computer Science. He has been nominated for five consecutive years for the University of Toledo Outstanding Advisor award. He has served on several NSF panels as a reviewer. He is a senior member of IEEE and a Program Evaluator for ABET Engineering Technology Accreditation Commission (ETAC).



Tod Shockey is a professor of mathematics education at the University of Toledo. Dr. Shockey earned his undergraduate degree from The Ohio State University, his masters from Montana State University, and his doctorate from the University of Virginia. His primary research interest is in ethnomathematics. He is a founding editor and current editor in chief of the *Journal of Mathematics and Culture*. The Journal is an open access publication with an editorial board that considers submissions in Arabic, English, Italian, Portuguese, and Spanish.



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See Appendix on the following pages



Appendix

INITIATE Summer Institute Schedule 2020

Weeks 0-3

		Week 0						
		Monday (June 8 th)	Wednesday (June 10 th)					
Legend:		Synchronous session						
		Asynchronous session						
		Checkpoint (Deadline for posting results)						
		GA's Virtual office hours (Optional)						
		1:00-4:00pm Technology Training Session: <ul style="list-style-type: none"> Introducing the team Intro to BB Intro to GoPiGo cars 		2:00-4:00pm Virtual Office Hours (All GA's)		INITIATE Summer Institute 2020 Schedule		
Week 1								
Monday (June 15 th)	Tuesday (June 16 th)	Wednesday (June 17 th)	Thursday (June 18 th)	Friday (June 19 th)				
9:00am Introduction to INITIATE, Acumen and taking surveys (PI's & Dr. Weber)	Sub-question 1: What are the demographics and needs of differently abled people in Toledo? <ul style="list-style-type: none"> Each group should watch videos in their respected group folder under Sub-question1: <ul style="list-style-type: none"> > Group 1: Watch Video 1.1.1 > Group 2: Watch Video 1.2.1 > Group 3: Watch Video 1.3.1 	Sub-question 1: What are the demographics and needs of differently abled people in Toledo? <ul style="list-style-type: none"> Activities continued: <ul style="list-style-type: none"> > Group 1: Watch Video 1.1.2 > Group 2: Watch Video 1.2.2 > Group 3: Watch Video 1.3.2 	Sub-question 2: What routes need to be planned in Toledo? <ul style="list-style-type: none"> Watch video 2.1 Watch video 2.2 Watch video 2.3 Watch video 2.4 Watch video 2.5 	Sub-question 2: What routes need to be planned in Toledo? <ul style="list-style-type: none"> Watch video 2.6 Watch video 2.7 Watch video 2.8 Watch video 2.9 Watch video 2.10 				
Introduction to Instructional Planning (All PI's)	3:00pm CHECKPOINT Sub-question 1	3:00pm CHECKPOINT Sub-question 1	3:00pm CHECKPOINT Sub-question 2	3:00pm CHECKPOINT Sub-question 2				
Overview of the course (All PI's)	3:00-3:30pm PI's synchronous session (All PI's)	3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)	3:00-3:30pm PI's synchronous session (Dr. Javaid)	3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)				
Introduction to Autonomous Vehicles and Introduce Driving Question (15 mins) (Dr. Javaid)	3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)		3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)					
Sub-question 1: What are the demographics and needs of differently abled people in Toledo? Go to Start Here folder and: <ul style="list-style-type: none"> Watch Video 1.0.1 Watch Video 1.0.2 	4:00-5:00pm Virtual Office Hours (All GA's)	4:00-5:00pm Virtual Office Hours (All GA's)	4:00-5:00pm Virtual Office Hours (Akshay)	4:00-5:00pm Virtual Office Hours (Akshay)				
Marshal for the day (Dr. Shockey)	Marshal for the day (Dr. Thihal)	Marshal for the day (Dr. Weber)	Marshal for the day (Dr. Thihal)	Marshal for the day (Dr. Shockey)				

Summer Institute 2020 Schedule – Weeks 0-1



Week 2				
Monday (June 22 nd)	Tuesday (June 23 rd)	Wednesday (June 24 th)	Thursday (June 25 th)	Friday (June 26 th)
Sub-question 2: What routes need to be planned in Toledo? <ul style="list-style-type: none"> Watch video 2.11 Watch video 2.12 Watch video 2.13 Watch video 2.14 Watch video 2.15 	Sub-question 3: How can we make smart cars safer and more convenient for the differently abled population? <ul style="list-style-type: none"> Watch video 3.1 Watch video 3.2 Watch video 3.3 	Sub-question 3: How can we make smart cars safer and more convenient for the differently abled population? <ul style="list-style-type: none"> Watch video 3.4 Watch video 3.5 Watch video 3.6 	Sub-question 4: Do smart buses meet the needs of the differently abled population? <ul style="list-style-type: none"> Watch video 4.1 Watch video 4.2 Watch video 4.3 	Sub-question 4: Do smart buses meet the needs of the differently abled population? <ul style="list-style-type: none"> Watch video 4.4 Watch video 4.5 Watch video 4.6
3:00pm CHECKPOINT Sub-question 2	3:00pm CHECKPOINT Sub-question 3	3:00pm CHECKPOINT Sub-question 3	3:00pm CHECKPOINT Sub-question 4	3:00pm CHECKPOINT Sub-question 4
3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)	3:00-3:30pm PI's synchronous session (Dr. Czerniak) 3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)	3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)	3:00-3:30pm PI's synchronous session (Dr. Oluoch) 3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)	3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)
4:00-5:00pm Virtual Office Hours (Akshay)	4:00-5:00pm Virtual Office Hours (Akshay)	4:00-5:00pm Virtual Office Hours (Subhrajit)	4:00-5:00pm Virtual Office Hours (Kiyam)	4:00-5:00pm Virtual Office Hours (Kiyam)
Marshal for the day (Dr. Weber)	Marshal for the day (Dr. Thihal)	Marshal for the day (Dr. Shockey)	Marshal for the day (Dr. Thihal)	Marshal for the day (Dr. Thihal)

Summer Institute 2020 Schedule – Week 2

Week 3				
Monday (June 29 th)	Tuesday (June 30 th)	Wednesday (July 1 st)	Thursday (July 2 nd)	Friday (July 3 rd)
Sub-question 4: Do smart buses meet the needs of the differently abled population? <ul style="list-style-type: none"> Watch video 4.7 Watch video 4.8 	Sub-question 5: How will attractions like the Toledo Zoo use smart car technology for differently abled people? <ul style="list-style-type: none"> Watch video 5.1 Watch video 5.2 	Sub-question 5: How will attractions like the Toledo Zoo use smart car technology for differently abled people? <ul style="list-style-type: none"> Watch video 5.3 Watch video 5.4 	9:00am-12:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)	
3:00pm CHECKPOINT Sub-question 4	3:00pm CHECKPOINT Sub-question 5	3:00pm CHECKPOINT Sub-question 5	12:00-4:00pm TEACHER PRESENTATIONS	
3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)	3:00-3:30pm PI's synchronous session (All PI's) 3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)	3:30-5:00pm Instructional Planning Time (Dr. Weber, Dr. Shockey & Dr. Thihal)	4:00-4:30pm Conclusion	
4:00-5:00pm Virtual Office Hours (Kiyam)	4:00-5:00pm Virtual Office Hours (Subhrajit)	4:00-5:00pm Virtual Office Hours (Subhrajit)		
Marshal for the day (Dr. Shockey)	Marshal for the day (Dr. Weber)	Marshal for the day (Dr. Weber)		

Summer Institute 2020 Schedule – Week 3.

STEAM Education for Engaging Learners: Our Summer Camp Experiences

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Abstract

This is a descriptive study that focuses on the STEAM activities that we conducted during the pandemic. An online summer camp in a suburban school in Maharashtra, India was organized with various activities associated with STEAM components. The samples in the study were twenty parents and thirty-two students from lower financial backgrounds who attended all of the online summer camp activities. This paper sheds new light on STEAM education and investigates its applicability during and beyond the pandemic. In this study we include observations of parents' support and their active involvement in their children's learning during the summer online camp activities, which were also found in their responses. Hence this study suggests that parents play an important role during online STEAM education, and it appears to have a positive effect on their children's performance. A well-planned online STEAM activity can be implemented for any age group which promotes fun oriented online school education where students are engaged and take ownership of their own learning.

Keywords: STEAM education, summer camp, school education, role of parents, online education

The year 2020, unlike any other year, confronted the unlimited, unprecedented, and unexpected challenges in every sector, including education. Though a quick shift towards online education brought many challenges, new approaches have also turned out which have provided opportunities for bringing new ideas during and beyond the pandemic, i.e., it will modify and improve the existing education system. One such improvement is STEAM education. The STEM acronym was introduced by scientific administrators in 2001 at the U.S. National Science Foundation (NSF). In 2006 it was extended, and a component of Art (the A) was added by Yakman (2012).

What is STEAM Education?

STEAM is an extension of STEM education where 'A' adds more creativity and innovation. Singh (2021) suggested that by incorporating art into STEM, students can use both their analytical and creative minds to solve complex problems. Yakman (2012) breaks the arts down into the sub-categories of fine arts, language arts, physical arts, manual arts, and liberal arts. STEAM education is a framework which binds together the various disciplines of Science, Technology, Engineering, Arts, and Mathematics with a strong foundation of creativity and emotions. According to Yakman (2012), STEAM education has been implemented to enhance the understanding of the structure between the fields of science, technology, engineering, arts, and mathematics. It supports meaningful learning and makes the student face global challenges. By integrating the arts with STEM, it helps to inculcate creativity, emotions, and aesthetics and develop a responsible person who will live for the betterment of society, which is in line with the thoughts of Reeve (2021): it is about teaching the content, practices, and processes that STEM uses to meet human needs and wants and to solve real-world problems, which is also supported by Wandari et al., (2018) as STEAM learning helps develop student creativity and prepares them to implement their knowledge in daily life.

The Importance of STEAM education

STEAM education proposes an interdisciplinary, inquiry-based and constructivist approach, which blurs the lines between the various disciplines, making the learning integrated. Thus, learning becomes more innovative and enjoyable by making the classroom student-centered and collaborative. STEAM education makes the learner competitive, creative, and a critical thinker who can solve the problems of real world situations like global warming, poverty, scarcity of water, etc. According to Reeve (2013), teaching STEM in primary and secondary education can help students become interested in STEM careers and build a nation's STEM educated workforce that can be used to meet the demands of business and industry in a complex and technology-driven economy.

Components of STEAM education

All components of STEAM education are woven together, which makes the students able to think critically and creatively to solve societal problems by making use of engineering or technology, which are the basis of students' mathematics and science education. Moreover, the backbone of STEAM education that keeps all components a unit is the creative design process and emotional learning.

The various components of STEAM education are:

- **Science** - For acquiring the skills of observing and solving real life problems and needs.
- **Technology** - The ability to make use of human-made technology for meeting the needs and challenges to make life more sustainable.
- **Engineering** - The ability to create, design, and apply the understanding of maths and science in real life situations for the betterment of society.

- **Arts** - It includes various arts such as Fine (Aesthetics), Language (Art of communicating, developing one's ideas and understanding perspective of others), Liberal (Social arts including History and Philosophy), and Motor and Physical (Art of expressing and using body language).
- **Mathematics** - Enables communication and critical analysis and how we make sense of the human-made and natural world using numbers and computational reasoning (Reeve, 2021).

According to Yakman (2012), prior to the concept of STEAM, many of these subjects were not considered critical to the end goal of developing students into highly skilled citizens, with abilities and qualifications that are in demand in the workforce. The language arts, for instance, have crossover with every other STEAM field because they focus on effective communication, while liberal arts are also considered important academic subjects. The second level of the pyramid (Yakman, 2008) is labeled as an integrated level at which students can obtain a broad scope of all the fields and a basic overview of how they interrelate by teaching them with a purposefully planned and reality-based interdependence.

Background of the Study

During lockdowns during the Covid pandemic, as everyone had to follow social distancing, students often became irritated at home because they were facing restrictions on their daily routine. Moreover, the online teaching was content oriented, and classes were teacher driven; some students found it lacked challenges and innovation with no scope for creativity. As the experimental school in this study is in a suburban area it is not well equipped with a science laboratory hence the students were not able to practice the curriculum-based experiments. Moreover, as the experiments were related to daily life experiences the teachers nonetheless taught them using a lecture method rather than demonstration or experimental. Hence, the school planned to make the challenge of online education an opportunity to give hands-on practice of various experiments using problem-based learning (PBL) and activity-based learning (ABL) to the students of underprivileged areas (Intha & Phusavat, 2021). In addition, a hobby session and robotics sessions were planned as they were not determined to cause any financial burden on the school or parents. Noticing the situation, the school in Maharashtra, India organized an online summer camp to make the learning innovative, engaging, interesting, challenging, and motivating to their students by implementing STEAM education. In addition, the study also sheds light on STEAM education in an online setting for the students of underprivileged sections. A summer camp of nine weeks was designed, in which each online workshop was planned as an individual component of STEAM to enhance the understanding of the structure between the fields of science, technology, engineering, arts, and mathematics as shown in Appendix A.

In this study we focused on the following questions:

Q 1. What online presentation skills and visual arts were shown by students during the STEAM summer camp?

Q 2. What were the parents' opinions about the STEAM summer camp activities?

Our Action/Project

Summer camp activities based on STEAM education were planned as shown in Appendix A. The various objectives were designed in accordance with the study of Reeve (2013), which suggests that activities and experiences in STEM education programs should have realistic learning objectives that students can achieve.

For implementation of our planning, a Zoom™ meeting was organized where the mentors gave instructions about the outline of all the summer camp activities to all the teachers, learners, and the learners' parents. The instructions were given in mother tongue (Marathi) for ease of understanding. The instructions given were about the work that was expected from the students during the activity viz; note taking and performing the activity-based learning, which they were expected to perform with the mentors. As the ABL workshop needed various materials for performing the experiments, the list was sent to the schools' WhatsApp™ group well beforehand. To conduct the activity on project-based learning, two live sessions were conducted in which the mentors explained about PBL, its importance, and types of PBL, and explained all the steps of PBL (plan, action, observation, and discussion). Also given was detailed guidance about various PBL activities that students had to do at their homes (Appendix B). The mentors assigned the various projects according to their grade levels. They gave detailed ideas about each project regarding its planning, implementation, data collection, and management to clear any doubts. The students were asked to present their project using PowerPoint (PPT) presentations after four weeks and gave the details about the structure of the PPT. All the mentors took care to use things that were required, which should be available at their students' workplaces or homes, to follow the rules and regulations during the pandemic, and to not create an extra financial burden on parents. The program was also based on the study of Georgette (2012), which suggests that STEAM can be implemented for engaging, hands-on and reality-based activities, yet inexpensively, for the common good of bettering public education for all, while meeting the learning standards' guidelines and STEM related goals. All parents were requested to help their child/ren during the execution of the various projects as parents play a major role during online classes, as emphasized by Yuniarti et al. (2021) who noted that parental participation is very important for the success of online learning. Parents can become an invaluable learning resource to children by attending various STEM-related workshops (Prius, 2019).

Study Methodology

This study was based on a descriptive research method investigating the effect of STEM education on the online presentation skills and visual arts made by students and the opinion of parents about summer camp activities. The study conducted an online summer camp exploring the influence of STEAM education by organizing various sessions, which included ABL in science, PBL in science and mathematics, hobbies, and robotics, in which parents and teachers gained a new perspective about the understanding of science, mathematics, and technology, which were fun-oriented and creative.

Analysis

To analyze the visual arts, PPTs of students', and semi-structured interviews of parents' content analysis were evaluated. Content analysis can be applied to a variety of data (including nonverbal data, such as pictures, drawings, gestures, etc.) and in relation to a variety of research questions (Figgou & Pavlopoulos, 2015).

Sample

The population of this study contains all of the students and parents who admitted their ward in SMGES, which is located in a semi urban area of Maharashtra, India. The sample was taken from them with eventually twenty parents and thirty-two students of grade three to seven attending all the online summer camp activities. The vernacular language of Maharashtra is Marathi.

Results

Given below are the findings related to the study questions.

Q 1. What online presentation skills and visual arts were developed and shown by students during the STEAM summer camp?

The school in which the study was incorporated is in a suburban area in which the low-income students were admitted. During the pandemic as students were at home giving instruction presented greater challenges to provide them with hands-on practice in online science education. Experiential learning in science helps students to understand the concepts in a more meaningful way based on deep and long-lasting learning. Understanding the challenges, the program developers designed various activities while considering the economic status of the family. The various sessions were designed such that the materials and the equipment that were required would be easily available at students' homes. The learning was designed in such a way that parents should not be met with any financial burden.

The aim of the program designers was to examine the effect of STEAM education on the online presentation skills and visual arts made by students. Findings from the analysis of the observation of the program designers revealed two major themes related to online presentation skills for PBL activities: A) PPT presentation and B) Visual arts.

In the next section the outcomes of the two themes are discussed. Table 1 gives outcomes of the two themes.

Table 1

Outcomes of two Themes (PPT Presentation and Visual Arts)

PPT presentation (Total students = 32)

Criteria (Sub-Criteria)	Excellent (No. of Students)	Good	Fair	Poor
Attractiveness (Design, layout, creativity, and neatness)	Exceptionally attractive Effective use of technological aids (4)	No use of any visual/ technological aids (14)	No creativity or neatness; slides were hard to read (12)	Distractingly messy, poorly designed, hard to read, spelling mistakes (2)
Content Knowledge of the topic	Strong understanding, answered questions(4)	Good understanding, answered a few questions (12)	Fair understanding, unable to answer appropriately (10)	Poor to no understanding, unable to answer (6)
Subject knowledge	Excellence in demonstrating the full knowledge (more than required); gave answers with explanation (3)	Basic understanding about the subject knowledge, ease in giving the answers (8)	Unfamiliar with the information, able to answer only basic questions (16)	Could not answer any questions (5)
Organization	Presented information about each project in a logical and in an interesting sequence, easy to understand (4)	Presented information about each project in a logical sequence (12)	Skipping around while explaining each project, difficult to understand (14)	Poor at presenting; no sequence of information (2)
English proficiency during Presentation	Addressed all the information verbally, completely reading from notes, no eye contact, no appropriate and accurate expression, poor and repetitive vocabulary, pronunciation was not clear (12)		Presented all the projects in their mother tongue (20).	
English proficiency during answering the queries	Understood the questions, answered the questions in their mother tongue (12)		Unable to understand the question, asked for translation of question, answered the questions in their mother tongue (20)	

Visual Arts			
Science and Math Models from Dough (Total students = 32)			
Mechanics	Precisely designed according to their age groups (6)		Lacked precision (26)
a. Science			
	b. Math	Precisely make 2-D & 3-D geometrical shapes (17)	Lacked precision (15)
Creativity	Science & Math	Creative work: attractive, innovative ideas and use of combination of various colors	Less creative, no innovation (15) No creativity (6)
Math Models from Paper (Total student = 23)			
Mechanics	Made types of angles, triangles, quadrilaterals (16)		Unable to make types of angles, triangles, & quadrilaterals precisely (7)
a. Paper cutting			
	b. Paper folding	Very precisely (7)	Unable to make with precision (3) Unable to understand the folding procedure (2)
Creativity	Used coloured paper and coloured sketch pens; cut and folded with accuracy (7)	Used coloured paper and coloured sketch pens; less accuracy in cutting and folding (9)	No use of coloured paper and coloured sketch pens; no accuracy in cutting and folding (7)

PowerPoint Presentation (PPT)

Each PPT was analyzed based on the five themes under four criteria: Excellent, Good, Fair, and Poor. The thirty-two students each gave an online presentation, which included the PBL activities. The program designers observed their presentation in synchronous mode and gave feedback based on the following five sub themes:

Attractiveness -The PPTs of four students were excellent. They used visual and/or technological aids effectively. Slide background and fonts complemented the material. They were exceptionally attractive in terms of design, layout, creativity, and neatness. The PPTs of fourteen students were good as they were attractive in terms of design, layout, creativity, and neatness. Obvious effort was seen in the slides, but they did not use any visual or technological aids. The PPTs of twelve students were fair: their PPTs had no creativity and neatness, and slides were hard to read because of distracting backgrounds or fonts. The

PPTs of two students were poor as they were distractingly messy and poorly designed. Hence, they were not attractive, hard to read, and contained spelling mistakes.

Content Knowledge - Only four students were excellent in their content knowledge as they showed a strong understanding of the topic, so they were able to answer topic related questions. Twelve students showed a good understanding of the topic as they answered a few questions about the topic. Ten students showed a fair understanding of the topic as they were unable to answer sufficiently about the topic, while six students showed poor to no understanding of the topic as they were unable to answer any topic related questions.

Subject Knowledge - Only three students were found to show excellence in demonstrating the full knowledge (more than required) by answering all questions with explanations about all of the projects. Eight students were assessed as good as they had a basic understanding about the subject knowledge, so they were at ease in giving the answers about all of the projects. Sixteen students showed a fair performance as they were unfamiliar with the information hence able to answer only basic questions about the projects, whereas five students showed poor performance: they could not answer any questions due to their lack of prior knowledge and related understanding.

Organization- Four students displayed excellence, presented in the information about each project in a logical and in an interesting sequence, which was easy to understand. Twelve students were good at presenting the information about each project in a logical sequence. Fourteen students were rated fair at presenting the information about each project because they skipped around while explaining each project, which made the topics difficult to understand. Two students were poor at presenting: there was no sequence of information in each of their projects.

English proficiency – a) English proficiency as observed during presentations: Twelve students addressed all the information verbally, but it was completely read from their notes, and no eye contact was made with the observers. No appropriate and accurate expression was observed. The students' vocabularies were poor and repetitive. The students did not speak clearly. Pronunciation was not clear. The remaining twenty students presented their projects in their mother tongue.

b) English proficiency as observed during answering the queries: Twelve students who presented their projects by reading from the notes understood the questions asked by the project director, but the remaining twenty students were unable to understand the question, hence each time the mentor translated the query for students' understanding. Despite that, all students answered the questions in their mother tongue.

Visual Arts

The students' visual art productions were analyzed based on two sub-themes, *Science and Math Models from Dough* and *Math Models from Paper*, which are further subdivided into Mechanics and Creativity categories.

Science and Math Models from Dough. Thirty-two students made visual arts according to their age groups in both math and science sessions in synchronous mode. Mentors gave the feedback based on the sub themes Mechanics and Creativity, which are further divided into science and math categories.

Mechanics.

- a. Science: Six students designed the dough models precisely according to their age groups, while twenty-six students lacked precision.
- b. Maths: Seventeen students were able to make 2-D & 3-D geometrical shapes using dough with precision. The remaining students were unable to precisely shape their model. Among twenty-three students, sixteen students made triangles from paper cutting very precisely but seven students were unable to make them. Only seven students were able to make triangles using paper folding precisely but sixteen students were unable to make the triangles with precision.

Creativity.

- a. Science: Eleven students showed a lot of creativity by designing the model attractively using innovative ideas and by using a combination of various colors of dough in science activities, while it was observed that fifteen students were less creative: no innovation was observed in their visual arts. In addition, six students showed no creativity.
- b. For Maths, among twenty-three students only twelve were able to make the triangles by folding the paper. Among them only seven students designed it precisely. Three students made the triangles, but they were not to the scale. The remaining two students were unable to understand the folding procedure.

Math Models from Paper. In giving the students the opportunity to look at the familiar concepts in geometry with a new perspective, the mentor used the cutting and folding of paper. The mentor demonstrated the different types of angle triangles, quadrilaterals, and proof for Pythagoras theorem by cutting the paper and demonstrating how to make an obtuse angle triangle, acute angle triangle, and right angle triangle, 45-45-90 and 30-60-90 degrees triangles using paper folding.

Mechanics.

Paper Cutting - Sixteen students made triangles precisely, whereas seven students were unable to make triangles with precision.

Paper folding - Seven students made the triangles very precisely by folding the paper, but three students were unable to make it with precision while two students were unable to understand the folding procedure.

Creativity. While making triangles using papers by cutting and folding, seven students used coloured paper and coloured sketch pens; they also cut and folded the paper with accuracy, whereas nine students used coloured paper and coloured sketch pens but less accuracy was observed in their cutting and folding of the triangles and seven students

did not use any coloured paper or coloured sketch pens. Moreover, no accuracy in cutting and folding of triangles was seen.

Results of STEAM Components

While designing various sessions the program designers took into consideration each individual STEAM component for each session and also took into account that each individual session would weave in all of the components. Thus, each session was designed on an integration of each of the STEAM components.

1. Science Component (**S**)—A major focus of conducting workshops on various experiments on the science component in which students learnt the concepts of like & unlike charges, centrifugal and centripetal forces, the relation between pitch and vibration, physical and chemical changes, separation of mixtures, and life processes.
2. Technology Component (**T**)—A workshop on Robotics with Witblox and PBL activities for presentations by students were designed for the technology component.
3. Engineering Component (**E**)—An engineering workshop was designed based on physical & chemical changes and separation of mixture components. Students designed a model of dispersion of light by using easily available materials.
4. Art Component (**A**)—A workshop was held on Hobby Learning, which was about collecting stamps, coins and notes, feathers, and making models from dough as a PBL activity were designed as the art component.
5. Mathematics Component (**M**)—A workshop on geometrical shapes using dough, paper cutting, and paper folding was designed as the mathematics component.

Outcomes of Performing Various Projects and Presentations

S component -Students learnt about various units and their conversions, concept of distance, importance and uses of water, and processes and factors affecting rates of germination, life processes and diversity in plants. They also understood the effect of environmental factors on the process of germination and the preparation of herbariums.

T component - Students learnt about how to make PPTs creative, interesting, and appealing to the audience and how to present. They understand media literacy (e-media, e-newspaper) and the importance of choosing appropriate content from the Internet.

E component - Students constructed plastic prisms using transparent sheets.

A component - Students learnt the construction of 2 dimensional shapes and models of various 3-dimensional shapes; they can draw maps and understand the process of designing and preparing herbariums and now they can prepare and present food.

M component - Students learnt to draw various 2 & 3 dimensional shapes, draw maps to the scale, how to calculate percentage and draw graphs, find ratios, and estimate the values. Students learnt about how to measure length, breadth, and height of various 2 and 3 dimensional objects and distance between two places.

Discussion

During the pandemic the atmosphere of the whole community was stressful. More importantly the students, parents, and teachers were struggling to achieve a firm strategy of online teaching. A shift in teaching strategy was needed. Hence a financially deprived school in Maharashtra, India conducted online sessions for their underprivileged students. As it was always a challenge for the school to set up a science lab, this school grabbed the opportunity of giving hands-on practical activities to their students. The school also conducted online Zoom meetings with eminent persons, for which students, teachers, and parents had never dreamt of before.

In the hobby session, students and their parents came to know about different countries, their flora and fauna, geographical regions, vehicles, history, and monarchy. The robotics session made it possible for the students to know about current technology and how robots substitute for human actions, which they never had experienced due to unaffordability. Taking into consideration PBL and ABL were designed with the materials available at their place.

The study found that STEAM education can help in inculcating an aesthetic sense: it is a part of art components, which was observed in dough models and the PPTs, which were made by students. It was found that though students were prepared for online presentations, they were lagging in their communication skills. English is their first language in school curricula, but they are not proficient in it, the reason for which they are behind is that interaction in English is not mandatory for them as reported by school authorities. During the presentation it was observed that many students had made efforts to make their slides creative and interesting by using visuals/videos and animations. They also made beautiful dough arts with attractive colour combinations.

Active involvement by the parents helped achieve an increase in the performance of students in terms of achieving technological, social, life skills, and various science skills such as observation, measurement, inferring, predicting, and classifying. Similarly, improvement was seen in mathematical skills such as critical thinking, analytical thinking, problem solving, and quantitative reasoning.

As the students at this school had never done online presentations or made models using coloured dough before and had never had hands-on science activities and maths-related projects to learn geometry, we can say that the students' performance in the form of attempting to achieve various skills may be considered a result of the impact of STEAM education and parents' support. This was also reflected during the parents' interviews.

Students gave their feedback, which showed that they found all the activities interesting and fun oriented. They enjoyed themselves while doing them. Examples of students' feedback at the end of online sessions included the following statements:

"My parents supported me for the various difficulties I came across during the PBL and ABL activities."

“These activities made us understand all the concepts more easily as compared to a physical classroom where our teacher demonstrates or explains theoretically.”

“I was more excited and curious while collecting data to reveal the finished product.”

“It made me understand the concept very easily as I daily see and work with the same things.”

“I always see the most physical and chemical change in my surroundings ... never thought science is everywhere.”

“I always made toy robots, which I get free on food items but today I learnt its use and science behind it.”

Students asked various questions during the session, such as “What are indicators?” “Why does turmeric turn red when it comes in contact with detergent?” “Do all robots have human-like structures?” The mentors explained and helped solve their doubts. Thus, it shows that curiosity is one of the most fundamental requirements for STEAM education to be successful and one should make sure to fuel the students' interest by explaining things that they do not understand (Pirus, 2019). Following are examples of the various activities (Figures 1-5).

Figure 1a

ABL – Separation of Mixtures

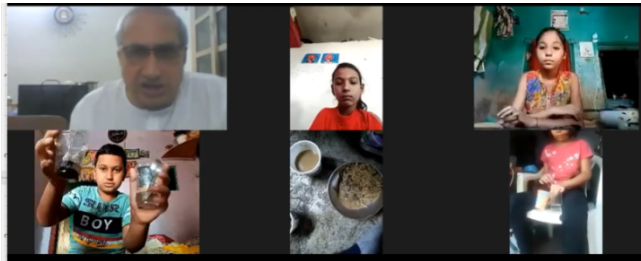


Figure 1b

ABL- Physical & Chemical changes



Figure 2

PBL - Modeling from dough



Figure 3

Various PBL activities

Picture of leaves	Name of leaves	Length of leaves	Type of leaves
	Coral Jasmine	7.1 cm	Simple leaf
	Tulsi	1.9 cm	Simple leaf



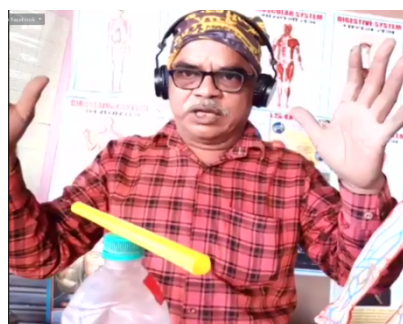
Figure 4

Hobby Session



Figure 5

Physics Experiment Session



Q 2. What are the Parents’ Opinions about Summer Camp Activities?

During the interview with the parents the project investigators came across certain things which shed some light on the active involvement of parents in STEAM activities.

The parents are from lower economic backgrounds, so they had never had time to see their child’s learning and progress. During the pandemic as children were attending classes from their home, parents found it interesting to attend the online classes. As the teacher explained all the content in their mother tongue, their interest was heightened.

When the school announced the summer camp activities parents started taking more interest in the learning of their children. They enthusiastically participated in the introductory session. They showed active participation during all activities by helping their children, which they never had done before in a physical school setting. The comments below support active participation of the parents.

During the feedback, which was taken at the end of all summer activities, most parents reported that all the sessions were inspirational, their child/ren were enthusiastic about participating in all the summer camp activities, and all the projects were informative (Table 2). Now that children started thinking on their own actions, they learnt technological

skills such as how to make and present a PPT during online sessions; they now understood the importance of water, the concept of conversion of units in mathematics, they can find the distance and direction of various cities using the Internet, understood the various methods of separation and how it is done, similarly the process of physical and chemical changes; now they know how much grocery is required on a monthly basis and their rates, and they came to know that the length of fingers is different from person to person. Although not a majority reported on other learning outcomes, a significant number of parents noted that their children enjoyed and learnt the concepts and various interesting activities related with physics, they started thinking on their own actions, and they learnt the skill of cooking. Below are comments shared by parents.

“It really makes children learn the material in an interesting way.”

“My child did maximum projects and they learned the material really well.”

“I liked that the children were given a choice to find a project they are actually interested in.”

“Children learnt the material in a fun learning way and also in a low-stress environment.”

“I was also excited to help my children whenever they required it. “

“The school kept us busy with summer camp activities during these stressful days of pandemic.”

“We use all the material for cooking, my child always sees and helps me with it, never thought that it is a part of my child’s learning.”

“I am a carpenter but never thought of teaching my children this way.”

Table 2

Parents’ Opinions About Summer Online Activities

Responses from Interviews	Responses % N
All the sessions were inspirational.	55% 11
Enthusiastic participation of child/ren	65% 13
Projects were informative.	75% 15
Child/ren started thinking on their own actions	40% 8
Child/ren learnt technological skill as how to make and present ppt during online session	65% 13
Child/ren learnt small but valuable things at an early age.	30% 6
Child/ren learnt what is a project? And how should it be done?	55% 11
How to conserve water and how to reuse it?	75% 15
Responses from Interviews, continued	Responses % N

The concept of conversion of units in Mathematics	65%	13
Find the distance and direction of various cities using Internet	40%	8
What are various methods of separation?	55%	11
Understood the process of physical and chemical changes	55%	11
Understood various concepts in physics	45%	9
Monthly requirement of grocery and its rate	65%	13
Learnt the skill of cooking	40%	8
The length of fingers changes from person to person.	75%	15

Further, parents shared their own experiences as shown in Table 3. They got the opportunity to upgrade their knowledge about various concepts of science and mathematics and they understood how aesthetic sense and creativity are woven around these subjects. They came to know about the importance of hobbies and how they should be inculcated. A significant minority of parents also reported that their misconceptions about robotics have been removed.

Table 3

Parents' Own Experiences on Summer Online Activities

Responses from Interviews	Responses (%)	N
Got the opportunity to upgrade their knowledge about various concepts of science and Mathematics	80%	16
Aesthetic sense and creativity are woven into science and mathematics	50%	10
About importance and inculcation of hobbies	40%	8
Removal of misconceptions about robotics	30%	6

Conclusion

This study shows that during online education various ABL and PBL activities can be done without a science laboratory or costly science equipment. It can be done at home, which is affordable for the students of underprivileged families. It suggests that STEAM education helps to engage students in their studies; it makes them curious and at the same time provides fuel to their curiosity. This STEAM summer program was conducted for underprivileged students, where students understood the concepts as explained in their

mother tongue (Marathi) first and then in English. STEAM education helps students to understand, explore and construct new knowledge. Students engaged with STEAM not only learn to be literate in a singular (silo) field, but they become life-long learners who are much more capable of adapting to and advancing the global society (Yakman, 2012). The study shows that in a multidisciplinary setting, trans-disciplinary pedagogical applicability of STEAM education can be applied effectively.

Parents' active involvement during online sessions shows the students' increased interest, active participation, clearing of doubts, smooth handling of gadgets, neatness in designing & performing experiments, and presentation of PPT. These activities show students' technological skill, media literacy, communication skills, life skills, and creativity which are 21st century skills (Reeve, 2021). It reflects parent help and support during PBL & ABL during online STEAM education learning. As the study included students of different age groups, it shows that STEAM education can be applied at different levels and that the students gain knowledge and skills appropriate for their grade levels (in this project, multi-age groups included students from Grades 2-7, thus some of the lower assessed scores are for the younger children). It also supports constructivist, inquiry based, collaborative approaches, which supports integrated learning where students actively participate in their knowledge construction.

Implications and Recommendations

The findings from this study have implications for teachers and educators globally who are promoting STEAM education. Similarly, involvement of parents play an important role during online STEAM education to create a positive effect on their children's performance.

Teachers should follow an inquiry approach, and an integrated approach to make the class more participatory for students. Science experiments should be linked with daily life experiences of the students. To make it most effective, emphasis should be given to developing science skills rather than on drill and rote learning.

Schools having inadequate infrastructure can implement activities and experiments using easily available inexpensive materials. Students should be encouraged to collect data from easily available sources and to carry out simple investigations. Virtual labs can be used to facilitate experiential learning.

The promotion and implementation of STEAM education need to be carefully planned. As Bedar (2020) recommended, teachers should be provided with enough valuable training opportunities on how to activate the STEAM approach to ensure meaningful learning for students and to increase their awareness for future careers including STEAM jobs.

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See Appendices on the following pages.

Appendix A			
Design of Summer Camp Online Activities Based on STEM Components			
Sr. no.	Week	Topic	Objectives of STEAM components
1	Week 1	PBL Workshop - Part I Science Models using Dough <ul style="list-style-type: none"> ● Scenery ● Geometrical shapes ● 2 D & 3D geometrical shapes ● Digestive System ● Respiratory system ● Flora and Fauna 	<ul style="list-style-type: none"> ● S - Learning about the digestive system, respiratory system, flora and fauna, Geometrical shapes, concept of time ● T - online presentation of models using PPT ● E - Design and make the various models using dough. ● A - making use of different colors of dough to make the 2D and 3D models of digestive system, respiratory system easy to depict, design beautiful nature, flowers and animals, ● M - Making 2D and 3D models of digestive system, respiratory system, flora and fauna, geometrical shapes precisely by adjusting the ratio of various parts, telling the time
2	Week 2	Science Workshop Part I : Physical & Chemical changes <ul style="list-style-type: none"> ● Energy and matter ● Five elements of nature ● Capillary action ● Chemical change - Milk into paneer by adding lemon ● Physical change- Melting of wax ● Sublimation process - Heating camphor ● Electrolysis ● Water is universal solvent ● Acid, base and Indicator ● Dispersion of white light 	<ul style="list-style-type: none"> ● S -Understanding the importance of matter and energy, various Physical & Chemical changes, Five elements of nature, Capillary action, acid, base Indicator, dispersion of white light, Electrolysis, water as universal solvent, ● T -Making the use of various equipments (house hold things) while performing experiments ● E - Performing experiments ● A -Art of making paneer, handling various things while performing experiments ● M - Performing all the experiment precisely

3	Week 3	<p>Workshop on Robotics with Witblox</p> <ul style="list-style-type: none"> ● Assembling a bot 	<ul style="list-style-type: none"> ● S - Understanding of robotics, its assembly gives understanding of the skeletal system, simple machines, friction and electricity ● T - Assembling of various parts ● E - Fixing, attaching, aligning the components of robotics ● A - Creatively assembling of various parts to make various designs ● M - Making the model precisely with reference to Measurements, alignment, weight management, specifications and configurations
4	Week 4	<p>Workshop on Hobby Learning</p> <ul style="list-style-type: none"> ● Collection of stamp, coins & notes, feathers 	<ul style="list-style-type: none"> ● S - Learning about the various scientific inventions, flora and fauna, metals and alloys ● T - learning how to preserve the various collection ● E - Design and making the albums ● A - Geographical & Historical awareness on global basis, international understanding, aesthetic sense ● M - understanding/ counting the numerals, geometrical shapes

5	Week 5 & 6	<p>PBL Workshop Part-II</p> <ul style="list-style-type: none"> ● Germination of seed ● Calculating usage of water ● Measuring fingers ● Prediction of distances ● Collection of newspaper cuttings ● Making Herbarium ● Planting saplings Projects ● Estimation of monthly grocery and electricity 	<ul style="list-style-type: none"> ● S - learning about the 2 & 3 dimensional shapes, various units and its conversion, concept of distance, importance and uses of water, process and factors affecting rate of germination, what is herbarium?, importance of reading a newspaper ● T - Online presentation of projects using PPT, understanding about media literacy (e media, e news paper) ● E - Measure length, breadth and height of various 2& 3 dimensional things , distance between two places, study the effect of environmental factors on process of germination, preparing herbarium , ● A - Drawing and making various 2 & 3 dimensional shapes, drawing maps, Design and preparing herbarium, aesthetic properties of seedlings and plants, preparation and presentation of food ● M - Drawing various 2& 3 dimensional shapes, drawing map accurately, calculating rate of germination in % and showing it in graphs, ratio of ingredients used while cooking, estimation
6	Week 7	<p>Science Workshop Part II - Separation of Mixture</p> <ul style="list-style-type: none"> ● Handpicking ● Threshing ● Winnowing ● Sieving ● Evaporation ● Distillation ● Filtration or Sedimentation ● Separating Funnel ● Magnetic Separation ● Centrifugation 	<ul style="list-style-type: none"> ● S - Learning concept, importance and types of mixtures, importance of blood donation, blood plasma separation, ● T - Making use of various equipments (house hold things) for separation of mixtures ● E - understanding the scientific method of separation, Handling the instruments and performing the various experiments ● A - art of making delicious dishes and soft drinks, performing the experiments precisely, India as a land of agriculture, ● M - understanding the concept of proportion,

7	Week 8	<p>Workshop on Experiment on Physics</p> <ul style="list-style-type: none"> ● Like & unlike charges ● Dispersion of light ● Centripetal & centrifugal force ● Sound- Pitch & vibration ● Law of inertia 	<ul style="list-style-type: none"> ● S -Learning the concept of like & unlike charges, centrifugal and centripetal forces, relation between pitch and vibration ● T - Making use of various equipments ● E - Handling the instruments and performing the various experiments ● A - art of designing, drawing, handling the instruments and using them for experiment ● M - understanding the concept of frequency
8	Week 9	<p>Math Workshop Geometrical shapes using Dough Paper cutting</p> <ul style="list-style-type: none"> ● Types of angle ● Types of quadrilateral ● Number system ● Proof for Pythagoras theorem <p>Paper Folding</p> <ul style="list-style-type: none"> ● Obtuse angle ● Acute angle ● Right angle ● 45-45-90 ● 30-60-90 	<ul style="list-style-type: none"> ● S - learning about the 2 & 3 dimensional geometrical shapes, various units and its conversion, perimeter, area and volume ● T -Making use of paper, pencil, ruler, compass, and protractor ● E - Drawing 2 & 3 dimensional geometrical shapes using paper, pencil, ruler, compass, and protractor ● A - making use of different colors of dough and paper cuttings to make different geometrical shapes ● M - Making the models accurately, finding the accurate answer of a given problem

Appendix B			
PBL activities according to STEAM components			
PBL activities, objectives, and STEAM components			
Sr. no.	Topic	Objectives	STEAM components
1	Measure the dimensions of 2-dimensional and 3-dimensional objects ex. Furniture, containers, wall etc. available in your home and find its perimeter, area and volume accordingly.	-To understand the concept of length, breadth, height, perimeter and area. -To understand the concept of conversion of units. -To apply the concept of length, breadth, height, perimeter and area.	<p>S - Learning about the 2 & 3 dimensional shapes, various units and its conversion, concept of distance, importance and uses of water, process and factors affecting rate of germination, what is herbarium?, importance of reading a newspaper, and learn to prepare food and healthy food habits</p> <p>T - Online presentation of projects using PPT, understanding about media literacy (e media, e newspaper)</p>
2	Measure the length of fingers of family members	-To study the relation between age and length of fingers.	
3	Measure the water intake of family members	-To study the effect of different types of soil on plant growth keeping constant parameters as sunlight.	
4	Study the process of Germination	-To know the water intake of family members.	
5	Find the quantity of water used in a day for various purposes in our home.	-To know the quantity of water used in a day for different purposes.	

6	Find the Monthly requirement of Grocery at our home.	-To know the price of various grocery items. -To know estimated monthly requirement of grocery -To know daily requirement grocery items -To know the quantity of remain grocery at the end of the month -To know the money spent on buying monthly groceries.	<p>E - Measure length, breadth and height of various 2& 3 dimensional things , distance between two places, study the effect of environmental factors on process of germination, preparing herbarium</p> <p>A - Drawing and making various 2 & 3 dimensional shapes, drawing maps, Design and preparing herbarium, preparation and presentation of food</p> <p>M - Drawing various 2& 3 dimensional shapes, drawing map accurately, calculating rate of germination in % and showing it in graphs, ratio of ingredients used while cooking, estimation</p>
7	Study the various shapes of things available at our home.	-To study various shapes of things available at home.	
8	Learn Cooking method - <ul style="list-style-type: none"> ● Coffee ● Tea ● Dal ● Meals 	-To learn the skill of making tea, coffee, dal etc.	
9	Make Herbarium	- To make a Herbarium	
10	Select a topic and make a chart using the cuttings from newspaper	-To collect the cuttings, make a chart on any topic from a newspaper.	
11	Distance between two places	-To know the distance between two places	