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Statistical Method to Assess Mathematical Skills of Primary School Students through STEM Education in Perspective of Block-Based Programming Scratch

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Abstract

In modern education the latest technologies accompanied with traditional teaching skills have enormous scope. Especially, in mathematical education the computational skills play a pivotal role. This paper presents the assessments made in mathematical education in relation to STEM and Scratch. Our goal is to investigate how the mathematical concepts like geometry, algebra when taught by new techniques based on visualization significantly improve the understanding of the primary school students. Our focus is on (a) emotional (b) behavioral (c) cognitive skills. Therefore, we designed an experiment in which 44 students were given a task accompanied by applying the traditional teaching methodologies. The same 44 students were given the same questionnaire of mathematical concepts after delivering lecture through Scratch and blended STEM education. Based on statistical analysis significant improvement (with p-value < 0.001) has been observed in students in terms of understanding circle, line and angle concepts. Moreover, training raised the cognitive, behavioral, emotional and overall engagement scores by 9.682, 1.045, 10.932, 21.227, respectively.

Keywords: Mathematical Education, STEM, Scratch, Pedagogical Skills, Block Based Pro-Gramming

The Problem and Its Background
Rationale

The traditional education in itself contains some loopholes which cannot produce desired results. The latest trends have been introduced to make mathematical education and other subjects based on skill-defined strategies. The lack of success in delivering mathematical education to pupils has contributed to the drawback of the way mathematical concepts are furnished to the students. This resulted in decreasing students' interest in opting mathematics as a subject and a career choice. Some innovative ways are required to make students comfortable with mathematics and convince them to choose it as a career in this field.

With the advent of new concepts Science, Technology, Engineering and Mathematics (STEM) where different fields merge together to bring a scientific solution to the problem exist in education. In their work, Sintema and Phiri (2018) discussed TPACK (Integrating Technology in instructional practices). Dorouka et al. (2020) have introduced the usage of tablets and apps in STEM education. Nguyen et al. (2020) inferred some criteria for an intelligent problem solver in STEM education. A review on STEM education is presented in the work of Wan et al. (2020). In Dare et al. (2019) it was reported that K-12 science teachers conceptualized using STEM education. (For literature review on STEM refer to Margot and Kettler, (2019); Martin-Paez et al. (2019)). A conceptual framework in STEM education was discussed in Kelley and Knowles (2016). The usefulness of STEM education in elementary and middle school was discussed in the work of English (2017). Radloff and Guzey (2016) investigated STEM teacher conceptions of STEM education.

The programming in understanding mathematics and physics concepts took a new role in education. The programming dependency in teaching has shown positive outcomes in students' understanding. The block-based programs, Scratch, is a popular and widely used programming tool in primary and middle school. The Scratch is used for creating shapes and games for academic purposes. Topalli and Cagiltay (2018) discussed improving programming skills of education in Scratch. Oh (2017) reported perception developed Scratch interest for non-major students. Papadakis et al. (2017) brought the appropriateness of Scratch in primary and secondary education. Ortiz and Romo (2016) discussed the importance of Scratch in secondary education. Hermans and Aivaloglou (2017) showed either to use Scratch or not by controlled experiment. Recently a new tool of Arduino has been added along with the Scratch in education. This combination of teaching was discussed by Fidai et al. (2020). Iskrenovic (2020) discussed geometry teaching with Scratch. Salac et al. (2020) reported TIPPSEE as a strategy in guiding students through Scratch activities. Rodriguez et al (2020) did an experiment on sixth grade students to learn how students perform in mathematics with Scratch. Franklin (2020) also shed light on the importance of TIPPSEE in Scratch activities. Dohn (2020) has discussed students' interest

in lower secondary mathematics using Scratch. Al-Othman (2020) presented Scratch teaching results on Riyadh students.

In all above studies the focus is on STEM education incorporated with modern gadgets. Our aim in this article is to collaborate Scratch in our studies and observe the learning outcomes after the introduction of programming in early years of education.

This paper is ordered as follows: Introduction is presented in Section 1. In Section 2 the Backdrop of the Pakistani students is given. Framework is discussed in Section 3. Findings of the study are given in Section 4. Conclusion is drawn at the end in Section 5.

Pakistani Students in Mathematical Skills

Various observations have noticed that Pakistani students do not take part actively in Mathematics classes. The reason for this non-serious attitude usually lies in the teacher, whose sole focus is rote learning and memorizing the formulas. Mathematics education is not as entertaining as it should be to produce good mathematicians. At grade 10 the students do not take interest in mathematics anymore.

The conventional way is typically accompanied by early childhood studies and high school education. There are no programming abilities added here. The modern trend is to implement coding skills as quickly as feasible to improve reasoning skills that allow students to achieve that level of learning. Students then become familiar with the system of programming at this early age and begin to learn from a simple programming language such as Scratch.

Framework

We incorporated Technological Pedagogical and Content Knowledge (TPACK) in our study to assess the students' abilities to perform in the class. TPACK has been used as a framework for designing and developing programs with more integrated knowledge. TPACK takes teachers' knowledge as intricate and versatile, evaluating technocentric approach that focuses on the accomplishment of technology skills separate from pedagogy and content.

This research is based on a quantitative study which includes pre- and post-tests pattern on the group. The students were given a test to solve the problems of geometry and algebra before introducing the Scratch. The data was collected as pre-test. Then after the treatment the group was tested again and significant change in understanding has been observed.

The group of 44 participants who belong to local government school of grade 4 were selected through systematic sampling. The school is in Rawalpindi, Pakistan. The focus of the study is to judge the existing analytical skills and compare with those after the

treatment. The information covers the different aspects including:

1. Cognitive engagement
2. Emotional engagement
3. Behavioral engagement
4. Overall engagement

Areas of Intervention

The students begin their activities in pre-test in solving very simple geometrical and algebraic concepts of mathematics. Later, a video was shown to the students making them to grasp the mathematical concepts in detail. Examination was conducted to evaluate the following three concepts:

1. Circle
2. Lines
3. Angles

Findings

The pre- and post- training evaluation scores of 44 students which include circle, line and angle are presented in Figure 1. This indicates the average pre- test score for the evaluation of lines concept is 2.136 with SD of 1.13 and after training the average post test scores for the evaluation of lines concept is improved to 5.602 with SD of 0.615. Training significantly increases the average line scores by 3.465 (p-value < 0.001), see Table 1, where the pre- and post- scores average differences with t-test scores and significance is presented. Similarly, the average pre- test score for the evaluation of angles concept is 3.80 with SD of 2.04 and after training the average post test scores for the evaluation of angles concept are improved to 7.57 with SD of 1.02. Training significantly increases the average angle scores by 3.773 (p-value < 0.001), see Table 1. Moreover, the average pre- test score for the evaluation of circle concept is 2.61 with SD of 1.45 and after training the average post test scores for the evaluation of circle concept is improved to 7.61 with SD of 1.061. Training significantly increases the average circle scores by 5.000 (p-value < 0.001), see Table 1.

The pre- and post- training evaluation scores of 44 students measure the behavioral, cognitive, emotional and overall engagement is presented in Figure 2. This indicates the average pre- test score for behavioral engagement is 18.4 with SD of 3.72 and after training the average post-test scores for the behavioral engagement is improved to 19.68 with SD of 3.99. Training significantly increases the average behavioral scores by 1.049 (p-value $= 0.049$), see Table 1. Similarly the average pre-test score for the cognitive engagement is 13.93 with SD of 5.60 and after training the average post test scores for the cognitive is improved to 23.61 with SD of 3.75. Training significantly increases the

average circle scores by 9.682 (p-value < 0.001), see Table 1. The average pre- test score for the emotional engagement is 11.25 with SD of 4.70 and after training the average post test scores for the emotional engagement improved to 22.18 with SD of 5.50. Training significantly increases the average circle scores by 10.932 (p-value < 0.001), see Table 1. Moreover the average pre- test score for the overall engagement is 43.80 with SD of 11.37 and after training the average post test scores for the overall are improved to 65.02 with SD of 11.33. Training significantly increases the average circle scores by 21.227 (p-value < 0.001), see Table 1.

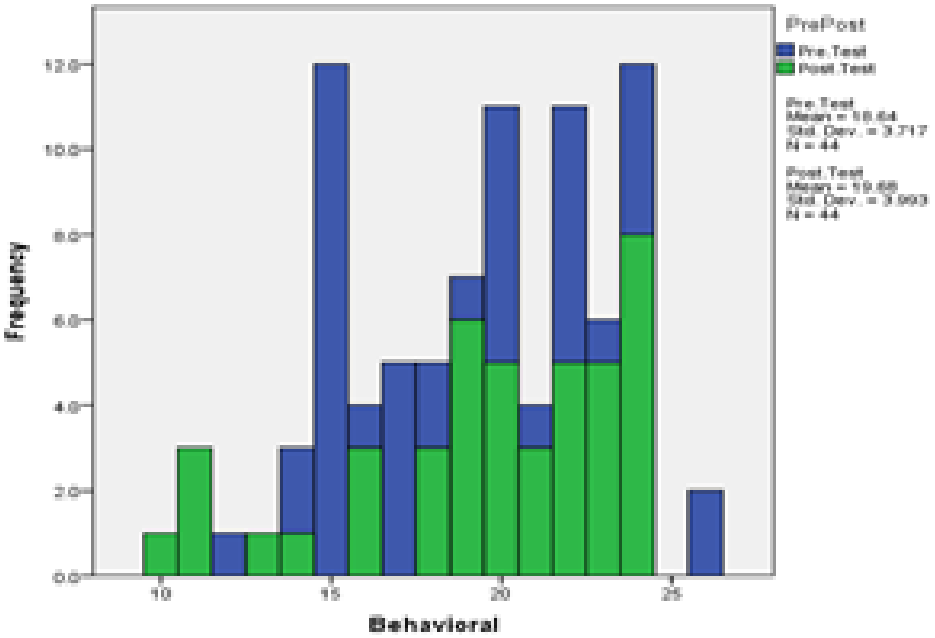

Figure 1: The pre and post training evaluation scores of 44 students measuring the behavioral engagement

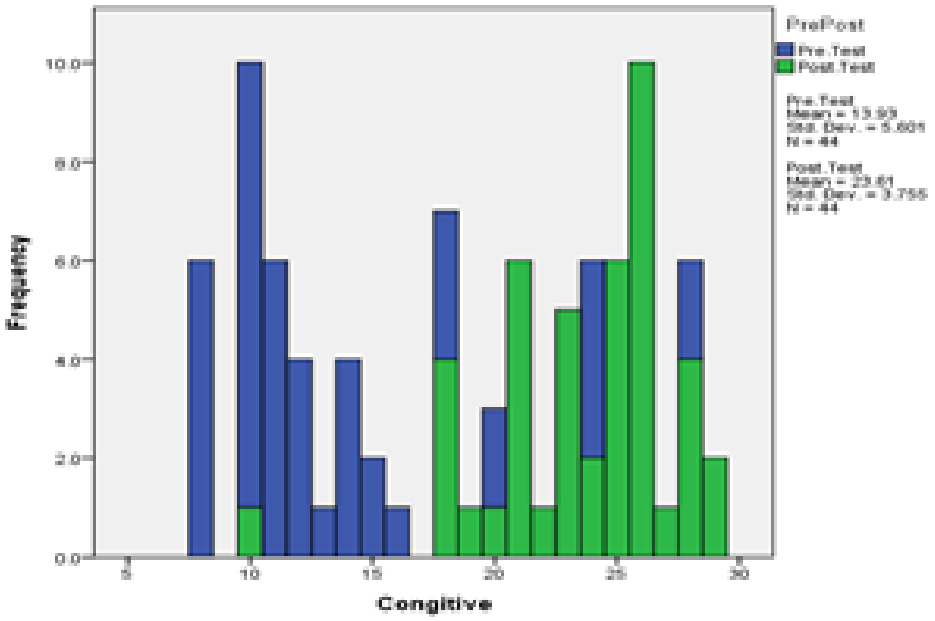

Figure 2: The pre and post training evaluation scores of 44 students measuring the cognitive engagement

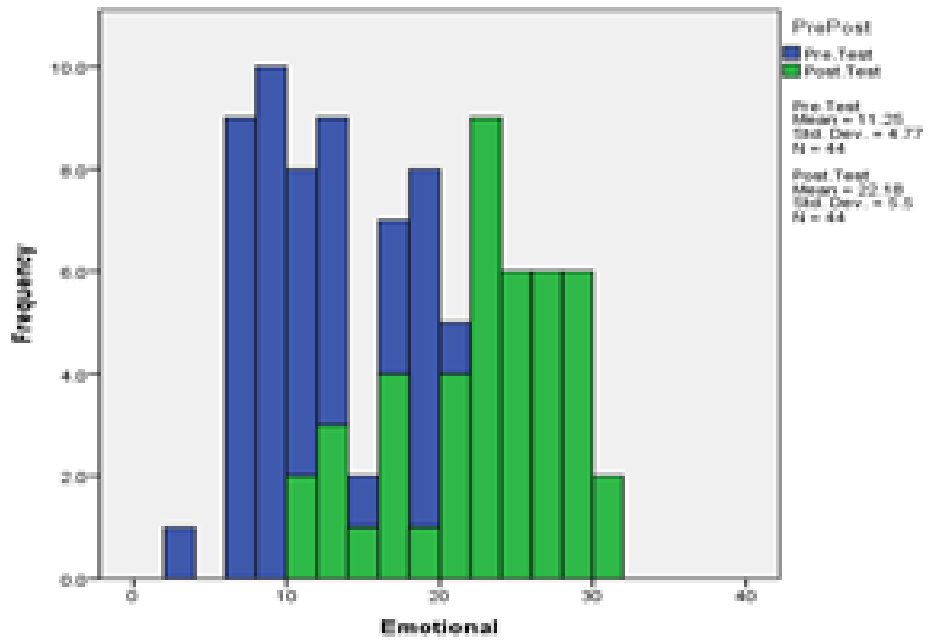

Figure 3: The pre and post training evaluation scores of 44 students measuring the emotional engagement

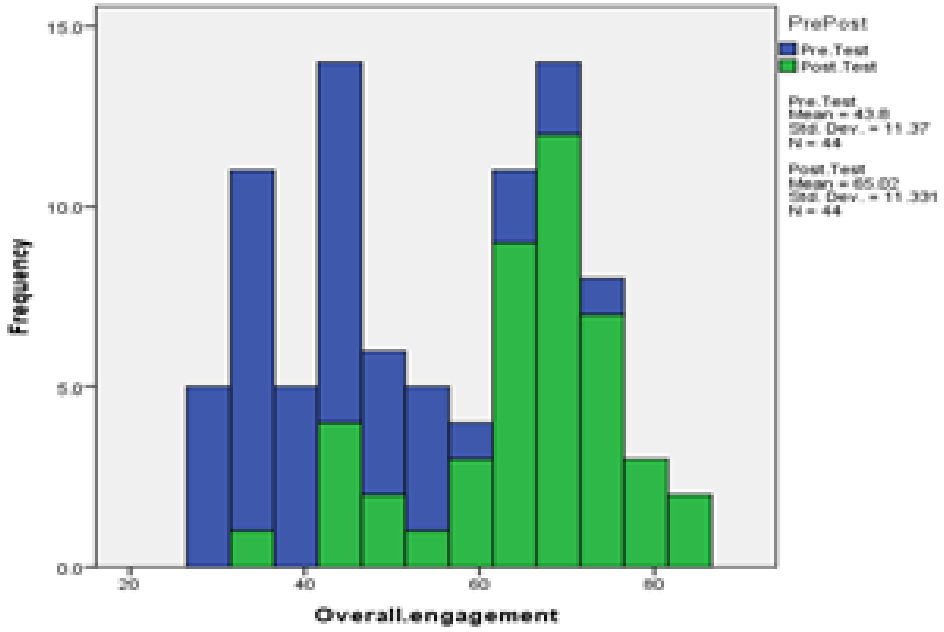

Figure 4: The pre and post training evaluation scores of 44 students measuring the overall engagement

Table 1: Statistical comparison of pre-test and post-test scores

	Paired Difference			
	Average	Std Devi.	T	p-value
Lines	3.4659	1.2822	17.930	<0.000
Angles	3.773	1.927	12.985	<0.000
Circles	5.000	1.698	19.531	<0.000
Cognitive Engagement	9.682	6.901	9.307	<0.000
Behavioral Engagement	1.045	5.595	1.240	.049
Emotional Engagement	10.932	7.148	10.145	<0.000
Overall Engagement	21.227	16.751	8.406	<0.000

Conclusion

The study is conducted in executing STEM education and Scratch together. Class 4 pupils of local Pakistani school with strength of 44 students are selected for this experiment. The summary of the results is presented here:

- An experiment on 44 students to measure mathematical skills in Pakistani perspective is conducted.
- Adding Scratch in curriculum might increase learning mathematical skills which can result in significant improvement in understanding.
- Statistical analysis proves significant improvement of $p - value < 0.001$ in understanding circle, line and angle.
- Training raised the cognitive, behavioral, emotional and overall engagement scores by 9.682, 1.045, 10.932, 21.227, respectively.

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