Sir Syed Journal of Education & Social Research
Vol. 3, Issue 3, 2020 (July – September)
ISSN 2706-6525 (online), ISSN 2706-8285 (Print)
ISSN 2706-9362 (CD-ROM), ISSN 2706-6525 (ISSN-L)
DOI: https://doi.org/10.36902/sjesr-vol3-iss3-2020(335-344)

SJESR
Sir Syed Journal of Education & Social Research

Technology Enhanced Formative Assessment for Students' Motivation in Mathematics at Elementary Level

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Abstract

Technology Enhanced Formative Assessment (TEFA) is an advanced and evidence-based pedagogical approach for science and mathematics teaching using a classroom response system. Question-driven instruction, dialogical discourse, formative assessment, and meta-level communication are four core principles on which TEFA is built upon. These are implemented through a question cycle in the classroom. Eight weeks duration intervention study was carried out in two urban high schools, one from each stratum (i.e., boys and girls) using a non-equivalent comparison group quasi-experimental design on a sample of 183 participants. The study participants included 42 girls and 47 boys in the experimental group, whereas 54 girls and 40 boys in the control group from the 8th-grade mathematics class. Students' mathematics motivation survey using IMI (i.e., intrinsic motivation inventory) was used to measure students' mathematics learning motivation levels. Two-way ANOVA was conducted to assess the motivation level of the students. Analysis of the results showed that the experimental group motivation level was significantly higher than the control group.

Keywords: Classroom Response System, Pedagogy, Mathematics, Motivation, Formative Assessment

Introduction

Teachers practice various instructional methods to involve and activate their students in the teaching-learning process. Activating students is a difficult task as many intrinsic and extrinsic elements are motivating forces for students. Class Response System is of an excellent technique to sustain an extreme level of student involvement and motivation as the lecture method ends motivation and reduces concentration on content (Duncan, 2005). According to Beatty (2004) and McLoughlin (2008), CRS-based instruction creates students' active participation in the learning process. The implementation of technology in the classroom has been discussed by Muller, Sharma, and Eklund, (2006) and has been widely used at the postsecondary level as compared to the use of CRS at the secondary level (Lively, 2010; Sartori, 2008). Further, these studies focused on the use of CRS only in the classroom and not talked about the pedagogy involved. The application of CRS based instructions in elementary and secondary education is still uncommon. To bridge this gap, the present study has been designed to explore the effectiveness of TEFA for student's mathematics learning motivation at the elementary level.

Literature Review

Research on the use of a CRS shows that this technology increases the motivation of college students (Gauci et al., 2009). However, to get the maximum benefit from this technology, a suitable pedagogy should be used with CRS. Numerous pedagogies relate to the Active Learning theories, Constructivism, and implementation of CRS technology. Some out of these are Peer Instruction (Crouch & Mazur, 2001), Assessing to Learn (Dufrense & Gerace, 2004), and Technology-Enhanced Formative Assessment (TEFA) (Beatty & Gerace, 2009). Technology-Enhanced Formative Assessment (TEFA) is one such pedagogy for science and mathematics teaching with classroom response technology (Beatty., et al, 2009). Dufresne et al. (1996) developed a pedagogy "Assessing

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to learn" that used CRSs for formative assessment. Technology-Enhanced Formative Assessment (TEFA) is a modified form of a pedagogy "Assessing to learn" developed by Beatty and Gerace(2009). TEFA is built on four fundamental principles categorized as: *question-driven instruction, dialogical discourse, formative assessment, and meta-level communication*. These four principles are best implemented through the below question cycle.

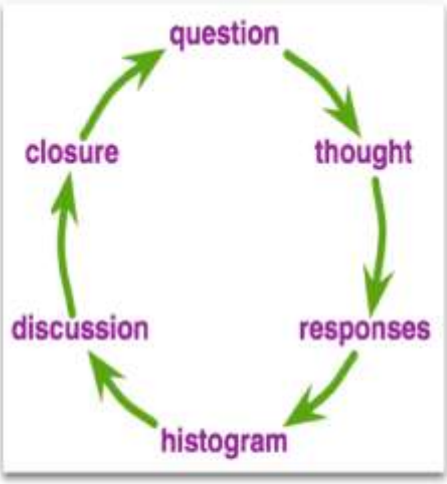

Figure 1. Question Cycle

Through this question cycle, the teacher asks a conceptual question to students within their zone of proximal development (Vygotsky 1978). Students think about the question alone or in small groups then record the responses through CRS. CRS displays a histogram of responses on the teacher's computer. After that whole-class discussion starts. Teachers elicit from students as many reasons and explanations as possible. This discussion is followed by a small lecture by the teacher and in this way, this question cycle ends and starts with another challenging question (Beatty & Gerace, 2009).

Class Response System (CRS) is mostly used at the postsecondary level (Beatty, 2004; Beatty & Gerace, 2009) and is not more popular at the secondary level. Students become active learners during instruction by using CRS (Jones, 2009). Research shows that students are more engaged and motivated in CRS classrooms (MacGeorge et al. 2008). Use of CRS technology motivated students to answer questions correctly, (a) improve student learning, (b) increased test scores, (c) improved student attention, and (d) enhanced interest of students in course content (Prather & Brissenden, 2009). CRS enhanced student engagement and motivation in crowded classes at the postsecondary level (Hall, et al. ,2005). Cain et al. (2009) indicated that the use of CRS increased student attention and motivation (Cain et al., 2009). CRS based instructions, peer instruction, enhanced student achievement and motivation at the secondary level (Allison, 2012). CRS improved student learning and motivation at the secondary level (Satori, 2008). CRS enhanced student motivation in 10th to 12th-grade students (Kay & Knaack, 2009). CRS improved student performance and motivation of science students in grade 6^{th} (Bloemers, 2004).

Objective

The main objective of the study is as under:

In what ways the Technology-Enhanced Formative Assessment affect students' subject-related motivation as compared to traditional instructional methods?

Method

Research Design

A static group experimental design was applied to perform the present study. Permission was obtained from the principals of the schools where this research was to be conducted. Permission for participation in the study was requested and obtained from teachers and parents of all the student participants at the beginning of the experiment. All teachers and participants were made aware that they had the choice to leave the research at any time. Students were encouraged by their teachers that participation and responses collected during this research were not related to them as individuals, but all gathered data would only be used for research purposes

Sample

The context of the present study is TEFA which is a CRS-based pedagogy focused on the philosophy of the constructivist paradigm that encourages students to take an active role in the teaching-learning process. The study was organized in two high schools (i.e., boys and girls) of urban area Haripur District Khyber Pakhtunkhwa Province, Pakistan. Two classes of grade 8th were selected from each school as an experimental and control group. Groups were assigned to each class. The sample size in each school is shown in the following table.

Table 1. Sample size

Stratum	Control Group	Experimental Group	Total
Boys School	40	47	87
Girls School	54	42	96
Total	94	89	183

Data Collection Instrument

Students' mathematics motivation survey using IMI (i.e., intrinsic motivation inventory) was used to measure students' mathematics learning motivation levels. Survey items established on two Dutch studies, the Intrinsic Motivation Inventory (Meijer, Eck, & Felix, 2008) and the COOL 5-18 cohort study (Driessen, et, al. 2012), were managed to measure students subject related motivation. Items were measured on a five-point Likert scale ranges from (1=completely disagree, 2=mostly disagree 3=agree to some extent, 4=mostly agree 5=completely agree). Though the reliability of the instrument is well established in different contexts but Pakistani context, its reliability was calculated using Cronbach's alpha which was .91. Both the control and experimental group students answered to students' mathematics motivation survey at the end of the intervention.

Procedure

Training of teachers and students on classroom response system

Experimental group mathematics teachers were given one-month training on TEFA. Experimental group participants in both schools (i.e., boys and girls) were also given training on the operation of the classroom response system (i.e., clickers) for one week before the intervention.

Intervention

During eight week intervention, the control group at both selected schools (i.e., boys and girls) were taught on average five hours a week using traditional instructional method, where the teacher used chalk and board, students noted down questions on their notebooks and were bound to reproduce the same on their homework copy on the next day. The experimental group was taught in a separate classroom specifically managed for Technology-Enhanced Formative Assessment (TEFA) pedagogy (i.e., CRS-based instruction).

Figure 2: Interactive Classroom Response System (clickers)

In the TEFA classroom, a classroom response system(clickers) was used to collect students' responses to multiple-choice questions before and during instructions. Each student was assigned a unique ID number; therefore, students were identified on the system through their ID numbers along with their names. A multimedia was used to display questions and students' responses on the screen when necessary during the instructional sequence. Clicker (i.e., a handheld student response device used by students to submit their responses to MCQs through radio frequency) was given to students. Teacher computer was connected to these clickers through radio frequency receiver wireless technology. The teacher was able to display the relevant question to students on screen as and when required in real-time. The teacher posed conceptual challenging question through the classroom response system. Time was given to students to think over it alone and in small groups, then respond through CRS (i.e., clickers). When the students completely decided about their response choice to a multiple-choice question, they were used to click on their selected response choice and submit answer through CRS. The teacher received students' responses on their computer through software and responses histogram and pie-chart were automatically displayed (see fig 2 and 3). Thus, the teacher was able to check students' responses in real-time, judged their conceptual comprehension, and adjusted instructions accordingly in real-time.

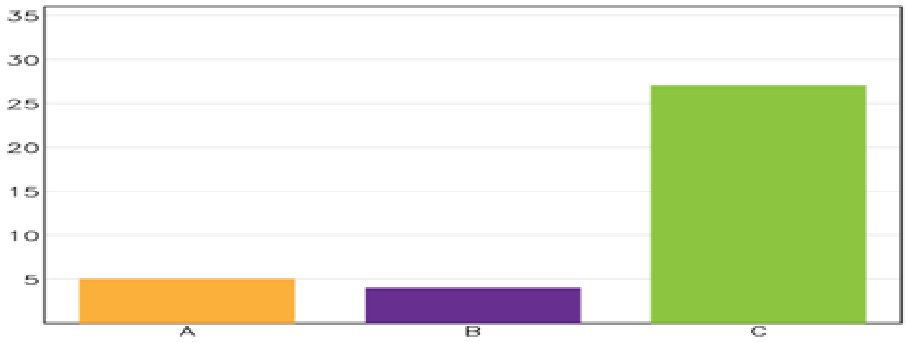

Figure 3. A histogram of students' responses to a question posed by the teacher

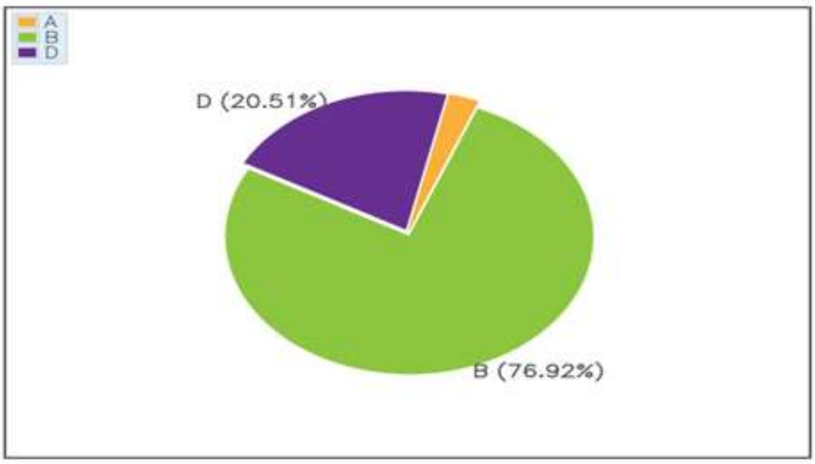

Figure 4. A Pie Chart of students' responses to a question posed by the teacher

Results

The main objective of this study was to find out the impact of Technology-Enhanced Formative Assessment pedagogy on students' mathematics motivation at elementary level in two high schools in Haripur District. After the intervention, the intrinsic motivation inventory (IMI) survey was used to measures a student's mathematics motivation level.

Kaiser Meyer Olkin (KMO) and Bartlett's test measures the strength of correlations among items. KMO statistics of .88, p= .000 is high and statistically significant that provide evidence that sample size is adequate to carry out a further factor analysis and the Bartlett's test of Sphericity is also statistically significant, it further corroborate that there are strong correlations among scale items.

Table 2. KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.880
Bartlett's Test of Sphericity	Approx. Chi-Square	572.886
	Df	10
	p-value	.000

All the items were strongly correlated with values between .57 to .72. It showed that all items were measuring the same construct.

Table 3. Inter-Item Correlation Matri*x*

S. No.	**Items Description**	**1**	**2**	**3**	**4**	**5**
1	Mathematics lessons are boring					
2	I like mathematics	.690				
3	I enjoy doing mathematics assignments	.697	.658			
4	I think mathematics is interesting	.633	.568	.723		
5	I think mathematics is important	.660	.634	.690	.699	

Table 4. IMI Survey items loading

Items Description	**Component 1**
Mathematics lessons are boring (Negatively worded question thus reverse for analysis)	.860
I like mathematics	.827
I enjoy doing mathematics assignments	.883
I think mathematics is interesting	.847
I think mathematics is important	.861

Extraction Method: Principal Component Analysis. a. 1 component extracted.

Further, only one factor was extracted explained 73.25% variance when used the principal components technique with varimax rotation and all the items were loaded on a single factor with strong loadings. It further supports the stance that there was a strong coherence among items to measure the construct of students' mathematics motivation.

Further, the participants' reply rate to the survey was 100% (89/89) for treatment group and 100% (94/94) for the control group. An ANOVA was applied to analyze the scores for each group for the IMI. For this purpose, assumptions of ANOVbetween-groups. Those were independence of observations, technology-enhanced homogeneity of variance and normality. A two-way between groups ANOVA was performed to compare the impact of technology enhanced formative assessment (TEFA) pedagogy on students' mathematics motivation. Further, participants were distributed into two groups based upon the instructional method (Control Group taught with traditional instruction method; Experimental Group taught with technology-enhanced formative assessment pedagogy). Further, Participants were divided into two groups based upon the parental support in homework (parental support = yes/no). Out of a total of 183 study participants, 69 were received parental support during intervention which becomes 38% of the total sample.

The outcome variable was found to be normally distributed and equal variances are assumed based upon results of Leven's test (F(1, 181)= *.1.953*, *p*= .123). There was a statistically significant difference in students mathematics motivation mean scores (F(1, 182)= *13.012*, *p*= .000) based on the instructional method. The magnitude of difference in the means (means difference= *.345*) and effect size was medium (partial eta squared= *.068*) with strong observed power .948. Results indicate that the instructional method explains a 6.8% variance in students' mathematics motivation. It means the treatment was effective to improve students' mathematics motivation. This finding is aligned with previous research findings where statistically significant improvements were observed in students' motivation for technology-enhanced instructional method interventions. Further, students' parental support in their homework assignments and home study in mathematics was found to be the significant predictor of students mathematics learning motivation (F(1, 182)= *6.828*, *p*= *.010*). The effect size of students' parental support was small (partial eta squared= *.037*) with observed power .74. Results indicate that students parental support explains a 3.7% variance in students' mathematics learning motivation. From the below figure it is evident that students' parental support significantly improved students' mathematics learning motivation across control and experimental groups, but the rise in students' mathematics motivation for the TEFA group is higher than for the control (i.e., traditional instructional method) group.

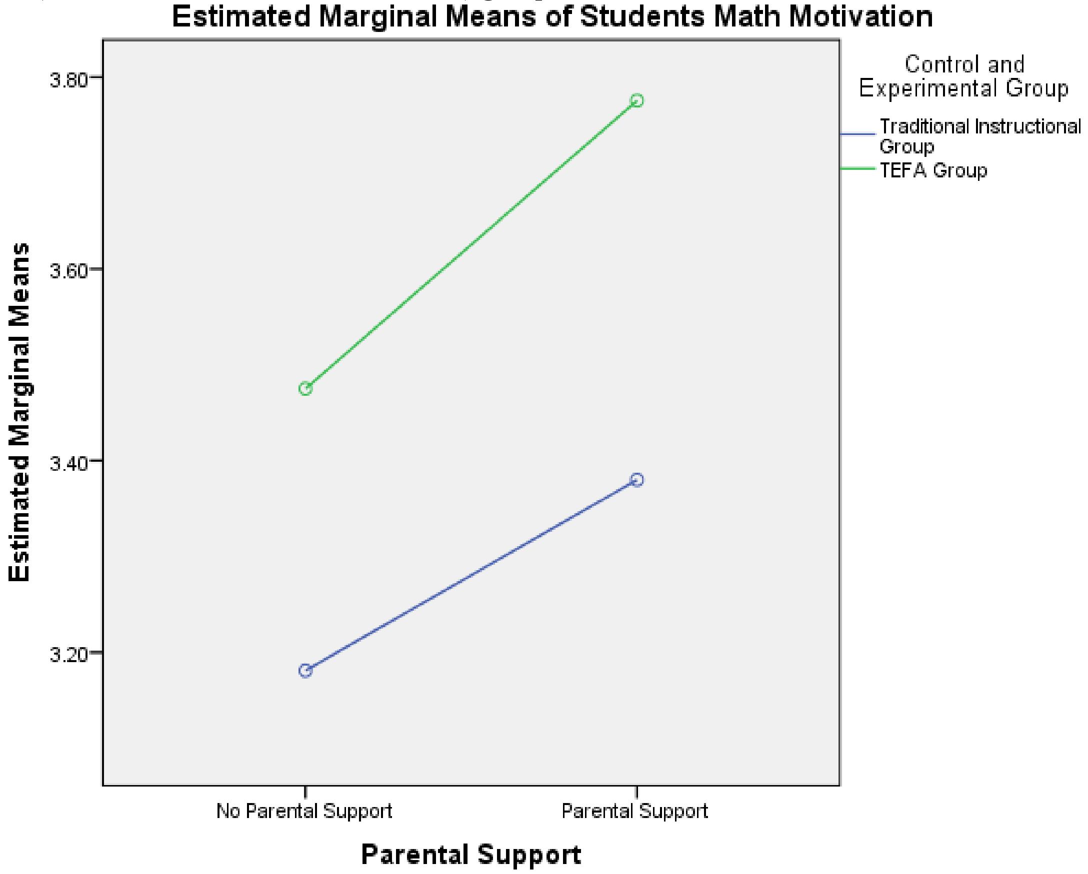

Figure 5. Parental Support and Mathematics Learning Motivation Across Groups

It shows that if TEFA is implemented in regular classrooms in combination with substantial students' parental support then higher learning motivation can be achieved. These results are in line with previous researches that used technology-based formative assessment, peer instruction, and other technology-based pedagogies. One of the reasons for the improvement in students learning motivation through parental support in homework may be the easiness that students felt when parents put their efforts to resolve their misconceptions about mathematics topics. They start to see mathematics as an easy to learn the subject and thus become more motivated to learn mathematics more enthusiastically.

Table 5. Two-way ANOVA Results on Students' Mathematics Motivation Scale Scores

Source	df	F	Sig.	Partial Eta Squared	Observed Power
Corrected Model	1	22.974	.000	.068	.99
Parental Support	1	6.828	.010	.037	.95
Pedagogy	1	12.012	.000	.068	.74

a. R Squared = .150 (Adjusted R Squared = .135)

b. Computed using alpha = .05

Discussion

The present study explored that in what ways technology-enhanced Formative Assessment is effective in improving students' mathematics-related motivation as compared to traditional instructional methods in mathematics at the elementary level.

The present study answers the aforesaid question that students who got TEFA instruction had higher mean scores for mathematics learning motivation than the students who received instruction through the traditional method.

This finding of ANOVA revealed that the use of TEFA instruction enhanced student mathematics learning motivation. Further, during data analysis, it was revealed that parental support during student's homework for mathematics at the middle level was a statistically significant impact on students' mathematics learning motivation in both treatment and control group participants. The parental support effect indicated that the students in both groups with parental support in their mathematics homework were more motivated than students who were in the same group but did not receive parental support during their homework of mathematics in eight grades. Although there was no interaction effect between treatment condition and parental support but the rate of increase in students' mathematics learning motivation for those who received parental support was higher in TEFA group students than their counterparts in the control group. This is evident from the two-way graph as well. Thus, parental support positively enhanced student's motivation to learn mathematics in eighth grade.

Results of this study support previous research findings, which proves that TEFA enhance student mathematics learning motivation level positively. Students are more engaged and more answerable for their learning by CRS based pedagogy (Zhu, 2007). Students perceive that motivation is increased using CRS-based pedagogies (Judson & Sawada, 2006). Attention is enhanced with the use of CRS technology and CRS based pedagogies (Horowitz, 1988). Students believe CRS and its implementation in regular classrooms with pedagogy is interesting and enjoyable and increase student motivation (Albon & Jewels, 2007). In TEFA, students' misconceptions are timely captured through multiple choice questions particularly designed with effective distractors. Through capturing student's responses to these questions, teachers decide about students misunderstanding of the concept and address those misconceptions through timely feedback. Previous researches have shown that timely feedback also significantly improves students' conceptual comprehension. This in turn enhances students subject learning motivation level. The same situation arises when TEFA is effectively implemented in the mathematics classroom at the elementary level. Hence results of this study corroborate the findings of past research that used technology-based pedagogies. The results of this study further show that parental support also contributes to subject related motivation.

Limitations and Recommendations

The present study examined the impact of TEFA on students' subject-related motivation in mathematics at the elementary level. However, this study faced a few limitations. First, the present research was conducted in two urban high schools in one district in one subject area with a sample of 183 participants. Future studies are encouraged to apply and expand this research work including both rural and urban areas of different districts in different subject areas to improve study generalizability. Replication of this study could be done with any of the following variations: using (a) a different validated survey for measuring motivation, (b) expanding the length of time for the instructional unit beyond eight-week time (c) using a different unit of study in math; (d) using a different subject area, (e) using a different grade level in the elementary setting, (f) Instead of quasi-experimental design, strong experimental design(random assignment of study participants) could be applied to improve the validity of the study.

Second, quantitative data was gathered in a self-reported way for analysis, so different qualitative research designs can be implemented to explore more information about the research problem at hand. Qualitative data such as semi-structured interviews, focus group discussions with students, or classroom observation, could be combined to develop a better understanding of the research question and corroborate the results from quantitative data.

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