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ORIGINAL ARTICLE

Effect of STEM Designed Activities on Academic Achievement of 7th Grade Elementary School Students in Force and Energy Unit

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ABSTRACT

The purpose of this study was to examine the effect of STEM designed activities on academic achievement of 7th grade elementary school students in work and energy unit. For that purpose, four STEM activities were chosen to be implemented in the work and energy unit. Semi-experimental research design was utilized for the research. Two different classrooms were chosen randomly as control and STEM group. 19 students were in the control group and 21 students in the STEM group. Both classrooms were instructed by the same teacher with the same instruction time. The only difference between the groups was the STEM integrated activities. Initial analyzes revealed that there was no statistically significant difference between the groups in terms of academic knowledge level prior the study. After implementing the STEM activities for the STEM group, statistical analyzes revealed that there was a statistical positive difference in favor of the STEM group. After a month, posttest was administered to STEM group in order to determine the retention level of the students. Analyzes revealed that there was no statistically significant difference between control group and STEM group.Analyzes revealed that there was no statistically significant difference between boys and girls in STEM group. It was concluded by the study that in the long-term STEM integrated curricula would benefit elementary science students and would decrease the gender gap in STEM related areas.

KEY WORDS: Elementary science; gender difference; STEM; STEM activities; students

INTRODUCTION

Science education is not only given to make people understand the nature of science but also helping them to understand phenomena in science and use the knowledge efficiently. In other words, people who have science literacy should be also able to understand the technical aspect of what is going on (Siayah et al., 2019). Thus, science education should enable people to understand the integration of physics, construction, digital technologies, virtual reality, etc. with each other which indicates STEM. As a result, in STEM education it is aimed at students comprehending science phenomena and basic principles of science while practicing engineering, design, and mathematics (Bevan, 2017). Consequently, education should enrich the learning of students and a learning environment should support different learners in terms of experience (Boudourides, 2003; Matthews, 2002). An enriched learning environment develops the skills such as problem solving, adaptation, improvisation, self-management, interpersonal relationships, and cooperative working. It is hoped that a person who has such skills will not have as many problems addressing the broad range of issues from personal health to international politics (Bybee, 2010).

STEM Education in Focus

Modern economies are based on qualified researchers thus STEM education is now discussed internationally and integrating STEM into education has become one of the main concerns in the educational system (Kennedy and Odell, 2014). For that reason, STEM education starts in kindergarten. This concern also requires STEM education should focus on both students and teachers. Since, increasing teacher performance will also increase students' academic achievement (Gonzalez and Kuenzi, 2012). However, science teachers at elementary schools are not STEM educators but they are professionals who teach in STEM. For that reason, they play an important role in students' learning to comprehend the science, technology, engineering, and mathematics and, their relationships with each other (White, 2014). For example, a study was done on engineering-based curriculum and involved teachers in the process. The results revealed that students in special education benefited the program (Guzey et al., 2016). Another study, similar to the previous example, designed STEM activities through engineering in a primary school. Those results revealed that students were able to apply scientific knowledge into practice and cooperation between the students' increased efficiency of learning since students were able to share scientific knowledge (King and English, 2016). Kurt and Park (2011) noted that as integration of STEM fields increased so did the learning of students, especially for elementary school students. STEM education helps students to develop higher order level of thinking and problem-solving skills.

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STEM Designed Curricula and Integration of Teachers

STEM and its success are not only related with students. For a better achievement, teachers should be also integrated to STEM education. Since teachers are generally not experts in the STEM fields it is logical to include them in the learning process and by this way teachers are also able to develop their own skills and realize the key points of process and learning which eventually involve students in the process and learning too. However, it must be noted that creating more pressure on teachers may also create other issues to be addressed. Curriculum designs familiar with teachers' instruction context may eliminate unnecessary tension (Stohlmann et al., 2012). There must be also collaboration among teachers, principals, and academics who could help each other and learn together from each other since, STEM is beyond discipline specific. Activities integrated to the lesson which are also related to conceptual knowledge create a dynamic learning (Dani et al., 2015).

STEM integrated curriculum studies indicate mixed results. It is promising to create better comprehension for early grades. Reasons for the mixed results or in other words not favoring studies may be due to study designs which merely apply aspects of engineering into learning material rather than creating high quality integrated curriculum designs (Guzey et al., 2017). Researchers try to determine effectiveness of STEM designed curriculums however assessment methods are based on previous curriculums. Hence, assessment results are in fact with respect to current curriculums thus to address the issue of assessment and evaluation, proper tests must be used (Harwell et al., 2015). Ejiwale (2013) reports absence of STEM teachers, poor preparation of teachers for STEM, poor preparation of students, not clearly connecting scientific fields with each other, lack of educational system, poor support from managers, poor content preparation, poor content delivery and poor real-life settings are the barriers in the successful implementation of STEM education. In that context, the purpose of this study was to determine the effectiveness of STEM activities for 7th year elementary school students in force and energy unit. To achieve the purpose of the study, STEM designed curriculum activities were integrated into the present curriculum.

This study sought to address the problem "Does STEM implemented activities make difference in academic achievement of 7th year elementary school students in a 'force and energy' unit with respect to current curriculum instruction?" The study also investigated a related sub-problem "Does STEM implemented activities make difference in academic achievement with respect to gender?"

METHOD

Research Design

This study was carried out with respect to quantitative research methods. The study design was pretest, posttest, semi-experimental design. This design was used to determine the effect of a variable on the concerned issue which was the effect of STEM designed activities on academic achievement (Karasar, 2009). A graphical illustration of the research design is given below in Figure 1.

Sample

Two different 7th grade classrooms from the same school were randomly selected for the study. One of these classrooms was selected randomly as study group and the other classroom as the control group. The study group consisted of 22 students; 1 student left the group thus the final sample consisted of 21 students. The control group consisted of 19 students and 1 student enrolled to the classroom after 2 weeks thus final sample consisted of 20 students. Before the study, both students and their parents were informed about the procedure in accordance with the research ethics of this study. Their informed consent were taken for experimental procedure. Both STEM and control groups were given pretest in order to determine any academic knowledge level difference between the groups.

Study Steps

Instructional materials provided for both groups were the same as implemented by Turkish Ministry of Education designed curriculum. Thus, the weekly duration of instruction was the same for both groups. Both classrooms were instructed by the same teacher who was working at the same school as an elementary science teacher. For that reason, the only difference between the groups was the four STEM designed activities implemented for STEM group whose study steps are explained below. Both groups finished the 'force and energy' unit with respect to present curriculum timing. As a consequence, no additional time was provided to the STEM group in order to carry out the study with respect to research design.

Study Steps for STEM Group

Four STEM activities were chosen to be implemented in the unit as experiments. These activities were listed in Table 1. By choosing these activities it was aimed that students would comprehend force, potential energy, kinetic energy, and their conversion to other phenomena. Students were required to make calculations where needed, explain the concepts both in building the materials, and relationship of science fields where applicable. The teacher observed both groups' processes and guided the groups by questioning the purpose of material building and its relationship with the science concepts. Students were also provided opportunities to explain the phenomena and its relationship within different science areas.

For example, students calculated the maximum height for roller-coaster, energy loss due friction, and made inferences about possible solutions. Illustrations of their work on the roller-coaster experiment carried out with students are shown below in Figures 2 and 3.

Students studied in groups and carried out each activity in accordance with timing in the present curriculum. After completing the unit, students were given academic achievement test (posttest).

Study Steps for Control Group

All the instruction, subunit order, materials, and experiments were carried out with respect to present constructivist curriculum implemented by Turkish Ministry of National

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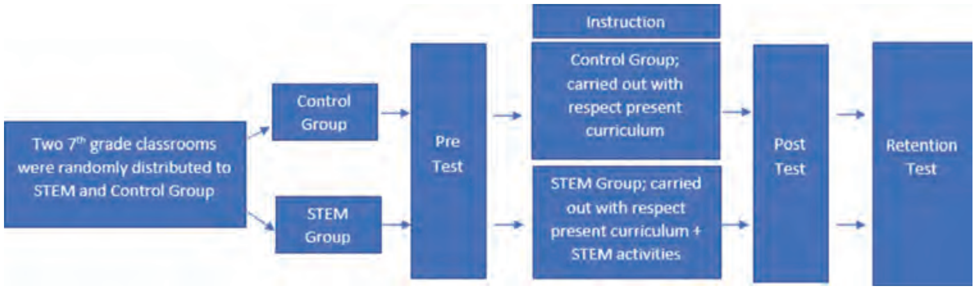

Figure 1: Research design

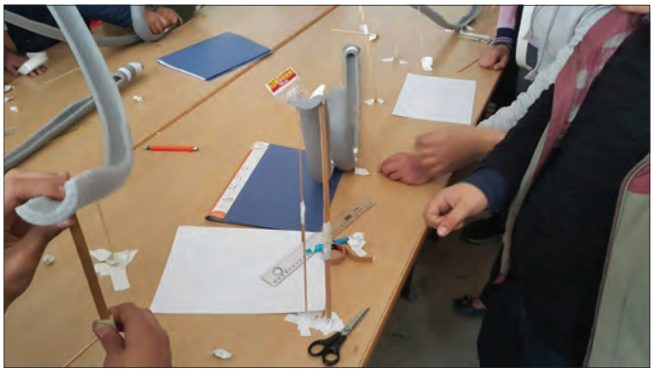

Figure 2: Preparing for the roller coaster

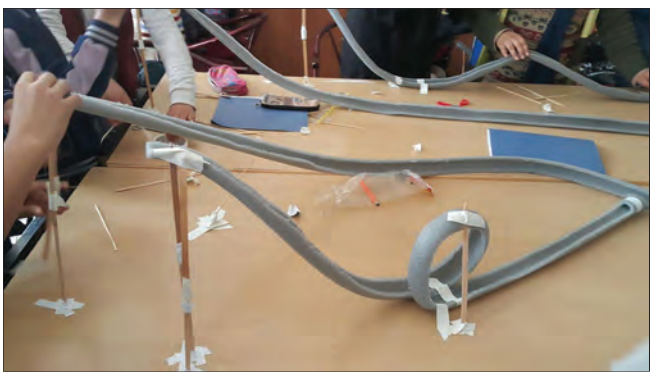

Figure 3: Carrying out the roller coaster experiment and assessing calculations and inferences

Table 1: STEM experiments

Activity	Phenomena
Egg-friction-air	Force – potential energy – kinetic energy - energy conversion
Syringe-fluid pressure	Force
Roller coaster	Potential energy- kinetic energy- energy conversion
Balloon-vehicle design	Air thrust

Education. After completing the unit, a posttest was given to students. The only difference between control and STEM group was the implemented activities for the research.

Achievement Tests

A pretest, posttest, and retention achievement test were applied to the students in both groups. Those tests were especially prepared for STEM designed curriculum and compatible with present curriculum (Yıldırım, 2016). Since these tests were prepared to be compatible both with STEM designed curriculum and the present curriculum it was considered as a reliable test. Additionally, it was aimed that proper tests would be used for the assessment of academic levels for both STEM and control groups. Hence, applied tests would not provide advantages to either of the groups. Consequently, the test results would not create an unfair evaluation for the groups. Kuder-Richard-20 (KR-20) reliability value of pretest was 0.62; Kuder-Richard-20 (KR-20) reliability value of posttest was 0.81. Kalaycı (2010) indicates a test is reliable if reliability value is between $0.6 < \alpha < 0.8$ and highly reliable if $0.8 < \alpha$.

Data Analysis

Analyzes for the normality of data

In order to determine correct analysis, normality of the data was checked for each test. Normality checks were done with respect to two different analyzes for exact interpretation. First kurtosis and skewness values were calculated with standard errors within 5% probability (Rose et al., 2014). Then, Shapiro-Wilk test was applied to confirm the normality of the data since it was advised for smaller samples (Kalaycı, 2010) and test results were indicated in respective topics and tables.

Normality analyses of pretest

Skewness value of pretest was 0.273 with standard error 0.369 and kurtosis value of pretest was 0.484 with 0.724 standard error. Thus, both values indicated that data was normally distributed within 5% probability and Shapiro-Wilk test confirmed the previous results. Shapiro-Wilk test results are shown in Table 2.

Normality analyses of posttest

Skewness value of posttest was 0.012 with standard error 0.378 and kurtosis value of posttest was -0.919 with 0.741 standard error. Thus, both values indicated that the data was normally distributed within 5% probability and Shapiro-Wilk test confirmed the previous results. Shapiro-Wilk test results are in Table 3.

Normality analyses of retention test

Skewness value of retention test was 1.049 with standard error 0.374 and kurtosis value of retention test was 0.916 with 0.733 standard error. Those values indicated that the data was not normally distributed within 5% probability and Shapiro-Wilk test results confirmed the previous results. Shapiro-Wilk test results are shown in Table 4.

FINDINGS

Analyzes of Achievement Test Results

Parametric and non-parametric tests were run with respect to normality test results which were presented in Tables 2-4.

Pre-test Results

Since data was normally distributed an independent samples t-test was run and results are shown in Table 5.

Independent samples t-test for the study's groups revealed that there was no statistical significant difference between the groups in prior academic knowledge level. Thus, for further analysis, differences between the genders in terms of prior academic knowledge level was also calculated for each group and results are in Table 6.

Table 2: Distribution of pretest

Shapiro-Wilk test			
Pretest	Statistics	df	Significance
Distribution	0.970	41	0.357

Table 3: Distribution of posttest

Shapiro-Wilk test			
Posttest	Statistics	df	Significance
Distribution	0.948	39	0.071

Table 4: Distribution of retention test

Shapiro-Wilk test			
Retention	Statistics	df	Significance
Distribution	0.915	40	0.006

Table 5: Independent samples t test for study groups

Independent samples t test for study groups						
Group	N	X	SD	Levene's test	t	Significance
Control group	19	14.05	4.275	0.983	-0.569	0.573
STEM group	22	14.77	3.829			

Table 6: Independent samples t-test for genders

Group	Independent samples t test for genders						
	Gender	N	X	SD	Levene's test	t	Significance
STEM group	Boy	10	14.00	3.801	0.860	-0.859	0.401
	Girl	12	15.42	3.895			
Control Group	Boy	8	13.00	4.175	0.773	-0.911	0.375
	Girl	11	14.82	4.378			

Independent samples t-test for genders revealed that there was no significant difference between the boys and girls within the groups with respect to prior academic knowledge level.

Posttest Results

Since both analyses confirmed that data was normally distributed then an independent samples t-test was run, and results are in Table 7.

Independent samples t-test for the study's groups revealed that there was a statistical significant difference between the groups in terms of academic knowledge level in favor of STEM group. Thus, for further analysis, differences between the genders in terms of academic knowledge level was also investigated for within STEM group and results are shown in Table 8.

Independent samples t test for genders revealed that there was no statistically significant difference between the boys and girls in academic knowledge level within the STEM group.

Retention Test Results

Since both analyses confirmed that data was not normally distributed then a Mann-Whitney U test was run, and results are in Table 9.

Mann-Whitney U test for study groups revealed that there was not a statistically significant difference between the groups in terms of retention level. Thus, for further analysis differences between the genders was also calculated for within the STEM group and results are in Table 10.

Table 7: Independent samples t-test for study groups

Group	N	X	SD	Levene's test	t	Significance
Control group	19	17.42	2.388	0.131	-2.176	0.036
STEM group	20	19.35	3.083			

Table 8: Independent samples t-test for genders

Gender	n	X	SD	Levene's test	t	Significance
Boy	9	19.00	3.841	0.006	-0.430	0.674
Girl	11	19.64	2.461			

Table 9: Mann-Whitney U test for study groups

Group	N	Mean Rank	Sum of Ranks	U	Significance
Control group	19	17.63	335.00	145.000	0.138
STEM group	21	23.10	485.00		

Table 10: Mann-Whitney U test for genders

Gender	N	Mean Rank	Sum of Ranks	U	Significance
Boys	10	8.55	85.50	30.500	0.083
Girls	11	13.23	145.50		

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Mann-Whitney U test for genders revealed that there was no statistically significant difference between the boys and girls in retention level within the STEM group.

DISCUSSION

Pretest results indicated that there was no significant difference between the groups in terms of academic knowledge level and it might be claimed as both groups are almost identical since the mean difference was only 0.72 point and in favor of STEM group (Table 5). For further discussion gender differences were also examined and it was observed that although girls' mean points were higher than boys, differences were similar for both control and STEM groups. Girls' mean was higher only by 1.82 points than boys in control group and 1.42 point was higher than boys in STEM group (Table 6). One might argue that these girls were more into academics and studied better than boys. Another argument might be proposed as these girls benefited more from Turkey's current curriculum designs than the boys. However, Wieselmann et al. (2020) indicated although girls are more into academic exhibitions in grades, boys benefit more than girls in STEM designed activities. These authors also claimed that a long-term integrated STEM designed curriculum would benefit both genders. Similar arguments related to outperformance of girls over boys are cited by Houtte (2004), Kretschmer et al. (2018), and Riegle-Crumb (2010). Be that as it may, both groups had similar academic characteristics and the gender effect also exhibited similarly in each group. For that reason, it may be concluded that any statistical difference in academic achievement occurred due to STEM designed activities.

Posttest analyzes indicated that after this study's activities, the STEM group had 1.93 higher mean point than control group (Table 7) and that difference was also statistically significant ($\rho = 0.036$). Thus, it may be concluded that these STEM activities helped these students to comprehend the phenomena in their 'force and energy' unit better than those students in the control group. Examining the data through the gender differences, it was observed that although boys' mean point increased, there was still a 0.64-point difference in favor of girls (Table 8) and that this difference was not statistically significant ($\rho = 0.674$). Yerdelen et al. (2016) emphasized that there was no significant difference between the genders in terms of STEM attitude and STEM related professions. On the other hand, Master et al. (2017) pointed out the opposite argument and claimed STEM designed activities may increase girls' positive efficacy and science attitude and, eventually would lead girls to choose professions related STEM fields. Be that as it may, posttest analyzes (Table 7) indicated that the STEM group had better academic achievement and that was statistically significant. The effectiveness of this study's STEM integrated education increased the students' academic performance, and this argument is supported by other research (Acar et al., 2018; Becker and Park, 2011; Dani et al., 2018; Judson, 2014; Olivarez, 2014; Schmit et al., 2019).

Studies indicate that STEM designed activities increase the comprehension level of the elementary school students related to science topics (Moreno et al., 2016). However, when retention levels of the STEM group were investigated, it was observed that there was no statistically significant difference ($U = 145{,}000$; $\rho = 0.138$) between STEM and control groups (Table 9). Cromley et al. (2016) indicated that retention level is related with cognitive development. Thus, it may be said that although STEM activities benefited to students, a short number of activities does not fulfill the cognitive development. In addition, when Table 10 was examined, it was observed that there was a mean rank difference of 4.68 in favor of girls. That case also implied that the STEM designed activities may help students comprehend the phenomena in short term and, in the long run girls tend to be more successful academically ($U = 30{,}500$; $\rho = 0.083$) as indicated by the significance degree. On the other hand, Rittmayer and Beier's (2009) study revealed the reason might be due to the case of self-efficacy and in particular related to STEM efficacy. Since boys have more positive values about their scientific skills they tend to perform less and in the long-term girls outperform over boys. Similarly, Pomerantz et al. (2002) pointed girls tend to outperform boys academically. Swiatek and Lupkowski-Shoplik (2000) proposed the similar arguments and claim that girls have more positive attitudes towards school. On the other hand, same researchers warn that this tendency more likely will change since girls' positive attitudes towards science tend to decrease as the age increases. For that reason, early interventions to guide girls into more enthusiastic science activities might provide positive outcomes (Levine et al., 2015). However, it should be also noted that there were opposing arguments claiming gender has no effect on attitudes too (Reddy, 2017).

Teachers having knowledge on STEM and STEM designed activities are more eager to implement the technology into classrooms. Consequently, students benefit from these activities (Felix and Harris, 2010). This study not only investigated the effect of STEM designed activities on students' academic success but also their teacher. The same teacher instructed two classrooms in the same school under similar conditions. One classroom had the STEM activities integrated to the curriculum which was the experiment group while the other classroom was only instructed using the current curriculum. So, the only difference between the groups was the implemented activities. Findings presented in Table 7 demonstrated that teachers who use the STEM designed activities help their students to comprehend phenomena better than other students who do not have STEM designed activities. Kendricks et al. (2013) stated that mentoring has positive effects on students' academic achievement. There are many studies done on teacher factors which indicate that teachers are one of the key elements in students' academic success (Ang, 2005; Hall et al., 1989; Jacobi, 1991; Ovando & Ramirez, 2007; Yunus et al., 2011). It is fair to claim that the difference in academic achievement between this study's groups occurred due to curriculum implemented for STEM group since teacher was

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the same for both experiment and control group. This claim is supported by those studies which indicate curriculum designs affect academic success (Basham et al., 2010; Graves et al., 2016; Hansen, 2014; Thomas, 2014).

CONCLUSION AND RECOMMENDATION

In the light of this study, it was concluded that this study's STEM related activities helped elementary school students to comprehend energy phenomena in science. Thus, it is important to include STEM activities in the science courses. On the other hand, curricula without STEM integrated activities which are only supported by short term activities would be more likely to result in success only for the short term. Finally, since literature reveals that girls tend to avoid STEM related topics and professions in the long term, it is important that science curricula are integrated with STEM related activities in elementary and high schools.

LIMITATION

This study was only carried out on one curriculum unit with a relatively small sample thus, findings and conclusions are limited and restricted with sample size and curriculum unit. A longitudinal study could be carried out with a bigger sample. Also, carrying out researchers with different curriculum topics in order to determine the effect of subject topics. Final limitation of the study is the grade level of students. Since the students participating in this study were studying at the 7th grade level studies might be carried out with different grade level elementary school students.

ETHICS COMMITTEE

This research was approved by Muş Alparslan University Ethics Committee with approval number 79236777-050.01.04

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