The Effects of a Robotics Program to Girls' Aptitude and Attitude in STEM

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Abstract

Women are underrepresented in STEM-related careers. Factors relating to this gender gap can be traced back further to how women perceive STEM during their basic education years. This study aims to investigate the effect of a Lego Mindstorm robotics program to high school girls' aptitude and attitude towards STEM in the Philippines. Forty-nine (49) female grade 10 students (mean age= 16) from a science-based curriculum high school participated in this study. Qualitative and quantitative assessments were used to measure the effectiveness of this robotics program. Quantitatively, assessments on the aptitude of the students, tests on gear knowledge, sensors, and computer programming, and Test of Science Related Attitudes and STEM Career Interest Survey were used. Qualitative assessment was done by thematic analysis of individual journals written by the students during the course of the robotics program. Results indicated that the students' aptitude significantly improved after the robotics program. Moreover, girls' attitude towards STEM did not change significantly after the program. However, the students highly expressed interest towards robotics through their

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journal entries. A highly significant correlation was seen between enjoyment of science lessons and career interest in science, and between attitudes toward technology and attitudes toward engineering. The paper discussed some implications and presented recommendations for the furtherance of the study.

Keywords: Robotics, aptitude, altitude, STEM-related careers, women

Introduction

Science, Technology, Engineering and Mathematics (STEM) play a significant role in a nation's development. It is important to develop policies that help reduce gender gap in STEM, as such issues have an impact to national and educational development (Akinsowon and Osisanwo, 2014).

Women are underrepresented in STEM fields: a problem that requires complex and varied solutions (Scutt, 2013). They are less likely to choose STEM careers than men (Drury, et al., 2011). The stereotype that STEM fields are more appropriate for men than women is still strong despite the progress in standardized math and science test scores among women (Quinton, 2014).

To address the gender gap problem at the educational level, various programs have been developed to increase girls' interests towards STEM influencing their choices to pursue STEM careers. Many of these programs involve robotics projects since they are considerably economical and handy (Weinberg, et al. 2015). For example, Massey (2004) developed a robotics curriculum for middle school year girls, which utilized Lego Mindstorms products. It introduced students to skills, knowledge and concepts required to understand future technology.

Studies have shown that robotics projects are effective pedagogical tools in teaching some concepts related to STEM. One study showed that a robotics-based science and technology curriculum significantly increased the mean scores on a test that measures general knowledge on science, engineering and technology topics and specific knowledge on the implemented Lego robotics curriculum (Barker and Ansorge, 2007). A robotics program also helped improve girls' attitude

towards science and technology, and allowed them to solve problems, to be creative, and to engage in constructivist learning (Ebelt, 2012).

While it is clear that robotics programs keep students actively engaged in STEM learning activities, it is less obvious whether these programs help students increase their interest towards STEM and their perceptions towards their ability to pursue STEM areas of study and STEM career choices or not (Weinberg et al, 2015).

Several studies have investigated the relationship between aptitude and attitude in the field of science. For instance, a study was conducted to test attitudes using the test of science-related attitudes (TOSRA) among students who joined a robotics competition. The results showed that that there is a correlation between positive views towards science and achievement in science. The same study implied that in order to improve the attitude of students toward science, they must engage in authentic science-related activities (Welch, 2010).

In this study, a robotics program was used to determine its effects on the attitude and aptitude of high school girls in STEM. To examine attitude, the respondents took TOSRA before and after they participated in the robotics program. TOSRA is specifically designed for secondary students and measures 7 distinct science-related attitudes or scales: career interest in science, leisure interest in science, enjoyment of science lessons, adoption of scientific attitudes, attitude to scientific inquiry, normality of scientists, and social implications of science. This test has been used, including in this study, as a pre-test and a post-test to determine any changes in science-related attitudes (Fraser, 1981). To examine aptitude, a robotics aptitude test was developed. Students took this test before and after they participated in the robotics program. It measures students' knowledge in computer programming, LEGO mindstorm gears and sensors.

This study aims to determine the effects of a robotics program to high school girls' aptitude and attitude in STEM. Specifically, it aims to answer the following questions:

1. How has the students' attitude towards STEM changed after the robotics program?
2. How has the students' scores changed from the pre-test to the post-test of the robotics aptitude test?
3. Is there a correlation in the aptitude and attitude of the students?
4. Is there a correlation among the different attitude components?

Methodology

The research setting is the Integrated Developmental School (IDS), the basic education department of the Mindanao State University - Iligan Institute of Technology in Iligan City, Philippines. Since IDS is a science-based curriculum high school, the students take additional science and math subjects on top of the regular required courses of regular high schools in the Philippines. For this study, forty-nine (49) female grade 10 students participated. The average age of the participants is 16 years old.

The research design is divided into three phases, namely, pre-test, implementation of the robotics program and post-test. The description of the methods in every phase is discussed in Table 1. The study is quasi-experimental in nature. Pre-test and post-test scores were compared and the statistical results were supported with qualitative data.

Table 1. The Research Design

	Attitude	Aptitude
Phase 1: Pre-Test	TOSRA- Test of Science Related Attitude Components: Attitude to Scientific Inquiry, Enjoyment of Science Lessons, Career Interest in Science STEM Career Interest Survey (Kier et. al., 2013) Components: Attitude Towards Mathematics, Attitude Towards Technology, Attitude Towards Engineering	Robotics Aptitude Test Components: Gears, Computer Programming, Sensors
Phase 2: Implementation of the Robotics Program	Journal writing of students for every station	Blended Learning through Station Rotation
Phase 3: Post Test	TOSRA STEM Career Interest Survey	Robotics Aptitude Test

Results and Discussions

Effects of Robotics Program to Students' aptitude and attitude towards STEM

Table 2 shows that while there is a highly significant difference in the aptitude of the students before and after the program, there was no noticeable difference in the attitude towards STEM. In the case of the change in the aptitude of the students, there were input mechanisms employed to increase the students' pre-test scores at the end of the program. The teacher provided lectures and hands-on activities that contributed to an increase in the students' skills in understanding gears, computer programming and using sensors, thus an increase in the post-test scores.

Table 2. Pre-test and Post-test Results of Aptitude and Attitude towards STEM

		Mean	N	Std. Dev.	Mean Diff.	Std. Dev. Diff	T	df	p-value
Attitude	Pre-test	3.41956	49	0.300528	0.007653	0.27348	0.196ns	48	0.846
	Post-test	3.41190	49	0.338160					
Aptitude	Pre-test	22.00	49	2.880	-1.714	3.089	-3.885**	48	<0.01
	Post-test	23.71	49	3.116					

** highly significant
nsnot significant

Table 2 shows that the students' attitude towards STEM before the start of the robotics program is 3.41956. The qualitative interpretation of this value is high, as shown in Table 3 below. The Post-test mean of 3.41190 also has a qualitative interpretation of high, which implies that the attitude level before and after the robotics program stayed at the same level. As for the case of the change in the attitude of the students, their attitude towards STEM is already pegged at a high value prior to the program. It appears that being enrolled in a science-based curriculum for three years has made them develop a more positive attitude to science. The post-test results showed that students' positive attitude was high towards STEM but the rating did not reach the highest level of the scale.

Table 3. Qualitative Interpretation of the Attitude Scale

Qualitative Interpretation	Equivalent Mean Rating
very low	1.00-1.70
low	1.80-2.50
moderate	2.60-3.30
high	3.40-4.10
very high	4.20-5.00

While there was no significant difference in the quantitative method, qualitative approach using thematic analysis of the students' journals revealed substantial themes regarding their attitude towards STEM. Journal writing allowed the students to express their feelings regarding their robotics learning experience. While not all students shared the same experiences as expected, three themes stood out- enjoyment, teamwork and perceived competency. These themes were deduced from the recurring words used across the different journals. Words with similar meaning were given specific category. For example, words such as *fun, enjoy, enjoyable,* and ***happy*** are categorized as Enjoyment. Table 4 presents some excerpts from the journal entries of the students:

Table 4. Excerpts from the Journal Entries

Enjoyment	Teamwork	Perceived Competency
The first time I saw the robot, it is complicated to look at but as we go on, it is actually fun and easy. (Student 32) *It was fun because the robot was able to run forward and backward, accelerate, turn around, detect sounds and detect black lines.* (Student 4)	*The work was made and done easier and faster because we were a group. We are united as one.* (Student 19) *Our team actively participated and the feeling is great knowing that you were working well as a team.* (Student 25)	*I learned that a light sensor is something that a robot can use to detect current ambient light level.* (Student 7) *I learned how to solve for the ratio of the gears and whether it is going up or down.* (Student 11)

Correlation between aptitude and attitude of girls towards STEM

Consequently, Table 5 shows the correlation of the aptitude and attitude of the students towards STEM. Based on the results, it appears that the girls' attitude towards STEM has no significant effect on their aptitude in STEM. A girl's interest or positive attitude towards STEM does not guarantee that she will execute STEM-related skills well such as those in a robotics program.

Table 5. Correlation of Aptitude and Attitude of Girls Towards STEM

		Aptitude (Pre)	Aptitude (Post)	Aptitude (Diff)
Attitude (Pre)	r	0.269		
	p-value	0.062		
Aptitude (Post)	r		0.047^{ns}	
	p-value		0.746^{ns}	
Aptitude (Diff)	r			-0.084^{ns}
	p-value			0.568^{ns}

^{hs} highly significant
^{ns} not significant

Correlation among different attitude components

In the development of the questionnaire to measure the attitude of girls towards STEM, the following six components have been established:

I Attitude towards scientific inquiry
II Attitude towards mathematics
III Enjoyment of science lessons
IV Attitude towards technology
V Career interest in science
VI Attitude towards engineering

Table 6 shows the difference in the pre-test and post-test results of each component while Table 7 shows the relationship of the components. Based on Table 7, among the six components, only Part II (Attitude towards mathematics) has a significant increase from the conduct of pre-test to post-test. Similarly, various studies have shown positive effects on the aptitude and attitudes of students towards math (Cejka et. al., 2006; Kimmel et. al., 2008; Nugent et. al., 2009).

Table 6. Difference of Pre-Test and Post-Test Results Across the Six Attitude Components

Part		Mean	N	Std. Dev.	Mean Diff.	Std. Dev Diff	t	df	p-value
I	Pre	3.2939	49	.47188	-.06327	.42803	-1.035ns	48	.306
	Post	3.3571	49	.51031					
II	Pre	3.6918	49	.66890	.17347	.44664	2.719**	48	.009
	Post	3.5184	49	.62339					
III	Pre	3.1939	49	.70870	-.08163	.67721	-.844ns	48	.403
	Post	3.2755	49	.51862					
IV	Pre	3.8286	49	.55076	.06939	.52289	.929ns	48	.358
	Post	3.7592	49	.45777					
V	Pre	2.9898	49	.46469	-.11837	.51828	-1.599ns	48	.116
	Post	3.1082	49	.47777					
VI	Pre	3.5194	49	.70036	.06633	.65139	.713ns	48	.479
	Post	3.4531	49	.58917					

** highly significant
nsnot significant

Results, as shown in Table 7, indicate that enjoyment of science lessons is highly correlated with career interest in Science and attitude towards technology is highly correlated with attitude towards engineering. Aptitude, on the other hand, is not correlated with any part of the attitude test.

Table 7. Relationship between Aptitude and the Six Attitude Components and Relationship Among Attitude Components

	I DIFF	II DIFF	III DIFF	IV DIFF	V DIFF	VI DIFF
Aptitude Diff r	-.215	.025	-.027	.086	.055	-.033
p-value	.139	.863	.851	.557	.705	.820
I DIFF		.187	-.009	.143	-.057	.195
		.198	.952	.327	.697	.178
II DIFF			-.104	.045	-.260	.268
			.478	.761	.072	.063
III DIFF				-.053	.473**	-.023
				.717	.001	.876
IV DIFF					-.066	.514**
					.653	.000
V DIFF						.131
						.369

** highly significant
nsnot significant

Conclusions and Recommendations

The underrepresentation of women in Science, Technology, Engineering and Mathematics (STEM) courses and later on in their chosen career path (UNESCO, 2015) results in untapped resources in a scientifically and technologically advanced world. This case of gender inequality in STEM can be traced back to how girls fare in STEM-related subjects. This study explored the aptitude and attitude of girls towards STEM before and after a robotics program. Results indicated that there are substantial positive effects on the girls' perception towards STEM. In exploring the different components of the girls' attitude towards STEM, it was found out that there was a significant increase of their positive attitude towards mathematics. Furthermore, it was discovered that the girls who enjoy science lessons have a positive career interest in science and girls' attitude towards technology is highly correlated with attitude towards engineering.

For the furtherance of the study, it is recommended that a comparative study between a science-based curriculum high school and a regular high school will be made. Since the study was concentrated on students with a highly positive attitude towards STEM, it would be recommended to use the same method among students with low or weak interest towards STEM.

Moreover, researchers can look deeper into the relationship of the robotics program and the girls' attitude towards specific fields such as mathematics or physics.

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