The Hands-On STEM Curriculum Design Promoting Science Learning and Career Self-Efficacy for Gifted Girls

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ABSTRACT
This study explored the differences in scientific learning interest, scientific learning motivation, scientific learning difficulties, career self-efficacy and career development before and after the implementation of the scientific hands-on STEM curriculum for gifted girls. The 10-hour curriculum mainly consisted three sets of theoretical and hands-on activities related to electrical, mechanical and temperature experiments. It also explored the difference between students in two different types of schools. A total of 32 gifted girls in the 11th grade participated. It used the pre-post questionnaire to analyze the change. After the curriculum, the results show that although there was no significant difference in career self-efficacy and career development, these students have increased their science interest and learning motivation. There were significant differences in the difficulty of science understanding and reading and the practical activities were are not easy for the students. Teachers, nevertheless, needed to help students to practice. There was a significant difference in verbal persuasion which meant that they felt encouraged. Moreover, the co-educational students improved significantly than that of girls in the single-sex school, especially, in the science learning motivation. It also showed that the science-related curriculum and hand-on activities were more beneficial to the improvement of girls' interest and motivation in co-educational school.

CCS Concepts
• Social and professional topics → User characteristics → Gender → Women •Applied computing → Physical sciences and engineering → Physics • General and reference → Cross-computing tools and techniques → Design / Performance

Keywords
STEM, Hands-on curriculum; Science learning; Gifted girls; Single-sex girls school; Co-educational school

ICEMT 2019, July 22–25, 2019, Nagoya, Japan

ACM ISBN 978-1-4503-7210-7/19/07…$15.00
https://doi.org/10.1145/3345120.3345135

1. BACKGROUND
The under-representation of women is particularly pronounced in the physical sciences and few than 1% had received a doctorate in either field [1]. For gifted girls, Grant, Battle, & Heggoy‘s study pointed that gifted girls who had interests in STEM (Science, Technology, Engineering, and Mathematics) sometimes changed their career aspirations during high school due to negative school experiences and even started to develop uncertain career aspirations [4]. Kerr and Gahm reminded the educators that although these differences might exist they were highly influenced by experience and quite malleable [7]. Some studies found girls and boys in co-education schools and classes would not receive the same educational concern, and boys are generally called on to respond to questions more than girls [3,8]. This study tried to provide a series of science curriculum and hands-on activities for girls to improve their science learning interest, motivation, difficulty, their career self-efficacy, career development, and tried to compare the difference of different educational environment. Girls feel comfortable and had higher achievement in the sciences in single-gender schools, and aided in self-confidence, assertiveness, and development of a strong sense of identity [5,10].

Moreover, according to the theory of Bandura’s self-efficacy theory, it outlined four sources of information that individuals can judge their self-efficacy: performance outcomes, vicarious experiences, verbal persuasion, and physiological feedback/emotional arousal [2]. These sources or performance help individuals determine if they believe they have the capability to accomplish specific tasks. Even more, people with higher self-efficacy would face difficult tasks as challenges rather than threats [12]. According to Bandura, performance outcomes or past successful experiences are the most important sources of self-efficacy. Besides, self-efficacy is also influenced by encouragement and discouragement pertaining to an individual’s performance or ability to perform [9].

Inquiry and hands-on/performance curriculum is very important in science education in recent years. Through the observation and inquiry provided by teachers, it helps students to learn scientific reasoning and logical thinking. According to Huang’s research [6], STEM hands-on curriculum which provides direct practical experience in the operation or functioning of mechanical/electrical materials can help students learn how to develop knowledge integration effectively with expectation and support from teachers and peers. Moreover, the key of knowledge integration in STEM hands-on curriculum is the support from others and self-confidences. So, if teachers can choose the issues by individual areas which students are good at, they can perform better.

2. METHOD

It used the questionnaire to understand the differences between those gifted girls from different schools (single-sex school and co-educational school) before and after entering in the science curriculum. There are 32 11th grade gifted girls (achievement test got over 97 percentile rank among all same-age students) from two senior high schools (20 students were from single-sex school and 12 students were from co-educational school). The questionnaire included four questions about improvement resources of career self-efficacy and five other subscales: 1) science learning interest (12 questions and contained three domains: interest in theory understanding, verification, and life application); 2) science learning motivation (9 questions and contained two domains: extra-motivation and inner-motivation); 3) science learning difficulty (20 questions and contained four domains: the difficulties in theory learning, difficulties in understanding, difficulties in transferring, and difficulties in time-managing); 4) career self-efficacy (30 questions), and 5) career development (18 questions and contained two domains: career attitude and career plan). It could explain the variation of 69.83%, 59.11%, 61.09%, 54.26%, and 47.72% of the five subscales, and had good reliability and validity.

In order to enhance the participation of female students in science and differentiate from the general science camp, we designed a series of 10-hour STEM curriculum combining theoretical explanations and operational hands-on activities. The female students can have a lot of practical experience and are able to be continuously encouraged and guided by the teacher. We selected two different kinds of schools and took four weeks to carry on this scientific curriculum in the same classroom. The processes of curriculum included scientific literacy discussions, hands-on equipment, scientific measurement, and analysis results. Especially, DIY curriculum design needed to consider the skill of using tool and the scientific practical ability. Therefore, it was very important to teach the use of basic tools before the course was taken. First, teaching these girls how to use of circuit assembly tools correctly, such as electric iron bracket, wood pulp sponge, soldering iron skills, as well as the cleaning of electric iron. Since the temperature of the soldering iron was about 250 ℃, it was necessary to remind the students to operate under the safety regulations. It was the first step in the hands-on curriculum to let them overcome the fear of tool's using and avoid possible dangers.

There were 4 sets of courses about teaching experiment and practical operation. Related teaching goals and processes were as follows.

2.1 Mini LED Coloring Device Assembly DIY / 3D Light Carving Card DIY

After practicing the welding technique, these gifted girls would be allowed to solder the soldering tin on the circuit board in sequence, and then checked the appearance of the solder joints and the amount of solder to evaluate whether the trainer can properly use and control the soldering iron. After completing the training of basic soldering technique, teacher introduced the functions, characteristics, and related physical principles of electronic components by slides and video, so that the girls can recognize various electronic components, such as (1) the steps of soldering color code resistors, and (2) soldering three-color LEDs. The steps were determined by the appearance of the common positive electrode and soldered to the correct position on the board. After the correct circuit assembled, students can make a mini LED color grading device during the course, and conduct LED color control and color light mixing test through the device to explore the changes of light and color.

2.2 Self-Made Transmission Spectrometer

The teacher, at first, reviewed the relationship between the color and wavelength of the light, the principle of the grating, and how to use the grating, such as how the optical disc acts as a grating and using the grating to separate the white light. Then, let students make a simple spectrometer by themselves. The parts are made of the plywood and cut by using a laser engraving machine according to the pre-drawn design. These girls can cooperate and assist each other so that every student is able to assemble the parts smoothly, and then use the jig to clip the spectrometer on the lens of the mobile phone. At last, the teacher showed how to use the mobile app to do the wavelength correction on the spectrum of the fluorescent light source. The calibrated spectrometer was capable of observing various light sources and displaying the spectrum which is the intensity of the light as a function of the wavelength.

2.3 Digital Thermometer

The digital thermometer was built with a temperature sensor and a programmable microcontroller. Compared with the commonly used thermometer, the biggest advantage was that the data can be wirelessly transmitted to the mobile phone, and the temperature change graph can be displayed on the screen immediately, and then the data can be downloaded and processed by the software for subsequent analysis. It can also measure the temperature changes of various liquids at the same time.

2.4 Bubble and Science

A lot of scientific phenomena can be observed by blowing bubbles. Observing the bubble film in the bottle, showed that the interference phenomenon is obvious because the thickness of the bubble film is close to the wavelength of visible light. When the bubble film is thicker, the longer wavelength-red light may be strengthened, while the bubble film is thinner, the shorter wavelength-violet light may be strengthened. When the bottle is placed horizontally and let the bubble film standing upright, its thickness gradually changes from top to bottom. We can see the stripes neatly arranged like a rainbow. In addition, based upon the surface tension of the liquid, we can blow out a humongous bubble and multi-layer bubbles, we can study the boundaries of the bubbles and make a bubble thermometer, etc..

We also set up a professional teacher community to discuss how to design the related curriculum in school to confirm student's learning interest and achievement. Furthermore, we would arrange the forum and workshop to improve teachers' abilities in advising and counseling for the girls' study in science.

3. RESULTS

The difference of science learning interesting, motivation, difficulty, career self-efficacy, and career development before and after hands-on STEM curriculum

According to the pair t-test analysis, we found that there were no significant differences in science learning interest, science learning motivation, career self-efficacy, and career development after the curriculum (p>.05). The only significant differences was the difficulty in science understanding and reading (See Table 2 and 3), such as "When I was on the science course, I often couldn't understand the teacher's explanation" or "I didn't understand what the teacher said in the science class, and even I didn't know how to ask questions". It showed that these related mechanical or electronic hands-on courses were unskilled for current senior high school students.

However, these difficulties were below the average (M=3) in addition to time's management. In the implementation of the hands-on STEM activities, it can be found that students have increased their science learning interesting and learning motivation after the curriculum (See Table 1). Their career self-efficacy and career development were lower than that before the curriculum. It meant that, for the gifted girls, the more they feel difficult in hands-on curricula or activities, the less confident they felt for their future science career. It was worth noting this kind of phenomenon. Teachers needed to pay more attention to the career guidance/counseling of gifted women in STEM.

Table 1. The statistics of science learning interesting, motivation, difficulty, career self-efficacy, and career development before and after hands-on STEM curriculum

Item	Sub-item	Pre-test	Post-test
Science learning interesting (SLI)	Theory, TH	3.66	3.73
	Verification, VE	3.74	3.82
	Life application, LA	3.77	3.82
Science learning motivation (SLM)	Extra-motivation, EM	3.34	3.40
	Inner-motivation, IM	4.16	4.18
Science learning difficulty (SLD)	Difficulty in theory, TD	2.86	2.86
	Difficulty in understanding, UD	2.33	2.52
	Difficulty in transferring, TRD	2.70	2.84
	Difficulty in time-managing, TMD	3.13	3.24
The improvement of career self-efficacy (I-CSE)	Emotional arousal, EA	3.03	2.90
	Verbal Persuasion, VP	2.97	3.06
	Performance outcomes, PO	3.13	2.97
	Vicarious experiences, VE	2.55	2.63
Career self-efficacy (CSE)		4.39	4.32
Career development (CD)	Career attitude, CA	4.12	4.01
	Career plan, CP	4.43	4.39

Table 2. The pair t-test of science learning interesting, motivation, and difficulty before and after hands-on STEM curriculum

	Item	Pair Difference M	SD	SD Err.	df	T
pair 1	SLI-TH	-.070	.626	.111	31	-.635
pair 2	SLI-VE	-.076	.679	.120	31	-.630
pair 3	SLI-LA	-.055	.523	.092	31	-.592
pair 4	SLM-EM	-.063	.625	.111	31	-.565
pair 5	SLM-IM	-.025	.512	.091	31	-.276
pair 6	SLD-TD	-.001	.479	.085	31	-.011
pair 7	SLD-UD	-.197	.455	.080	31	-2.449*
pair 8	SLD-TRD	-.133	.527	.093	31	-1.425
pair 9	SLD-TMD	-.115	.578	.102	31	-1.122

*$p<.05$

Table 3. The pair t-test of career self-efficacy and career development before and after hands-on STEM curriculum

	Item	Pair Difference M	SD	SD err	df	T
pair 1	I-CSE EA	.128	.660	.117	31	1.099
pair 2	I-CSE VP	-.096	.588	.104	31	-.920
pair 3	I-CSE PO	.158	.678	.120	31	1.319
pair 4	I-CSE VE	-.085	.607	.107	31	-.790
pair 5	CSE	.062	.625	.110	31	.566
pair 6	CA	.115	.415	.073	31	1.566
pair 7	CP	.034	.630	.111	31	.309

The statistics of science learning interesting, motivation, difficulty, and career self-efficacy in different schools

According to the result of the comparison, the difference between two different schools' students found that the science learning interest and motivation of gifted girls in single-sex school (*M*=3.84 & 3.86) before the course were higher than that of girls in the co-educational school (*M*=3.53 & 3.57). However, after the course, the co-educational students (*M*=3.95 & 3.77) improved significantly than that of girls in single-sex school, especially their science learning motivation. It showed that the science-related curriculum and hand-on activities were more beneficial to the improvement of girls' interest and motivation in co-educational school (See Table 4).

Table 4. The statistics of science learning interesting, motivation, difficulty, and career self-efficacy in different schools

Item	Sub-item	Pre-test Single-sex school	Pre-test Co-educational school	Post-test Single-sex school	Post-test Co-educational school
SLI	SLI-TH	3.68	3.65	3.56	4.02
	SLI-VE	3.91	3.46	3.75	3.94
	SLI-LA	3.94	3.48	3.79	3.88
SLM	SLM-EM	3.45	3.15	3.40	3.40
	SLM-IM	4.26	3.98	4.21	4.13
SLD	SLD-TD	2.74	3.05	2.77	3.00
	SLD-UD	2.30	2.38	2.52	2.53
	SLD-TRD	2.54	2.98	2.74	3.00
	SLD-TMD	3.12	3.14	3.25	3.22
I-CSE	I-CSE EA	3.00	3.17	2.94	2.92
	I-CSE VP	2.94	3.00	2.83	3.33
	I-CSE PO	3.06	3.17	2.89	3.08
	I-CSE VE	2.61	2.45	2.67	2.58
CSE		4.50	4.12	4.35	4.15

The difference of career self-efficacy and career development between two different kinds of schools

Before the curriculum, two kinds of schools showed no significant differences in the self-efficacy, career self-efficacy, or career development. After the curriculum, according to the analysis of Levene's test of homogeneity, there were no significant differences but only the performance outcomes where there is a difference between the variances in the population. There was a significant difference in verbal persuasion (feel encouragement) according to the analysis of independent sample t test (See Table 5). It meant that the gifted girls felt supported and encouraged through the practical curriculum. They also mentioned that this kind of hands-on curriculum was less frequent in the past, but it was very interesting and learned a lot from it.

Table 5. The t-test analysis of career self-efficacy and career development between two different kinds of schools

The performance after the curriculum	t-test for equality means				
	T	df	Sig.	M Diff.	StD err. Diff.
I-CSE EA	-.099	30	.922	-.022	.218
I-CSE VP	-2.216*	30	.034	-.430	.194
I-CSE PO	-.746	15.26[a]	.467	-.186	.250
I-CSE VE	.291	30	.773	.080	.274
CSE	.851	30	.402	.275	.323
CA	.101	30	.920	.030	.298
CP	1.526	30	.138	.412	.270

*p<.05, [a] Equal variances not assumed

The difference of science learning interesting, learning motivation, and learning difficulty between two different kinds of schools

Before the curriculum, two kinds of schools had no significant differences in science learning interesting, learning motivation, and learning difficulty. After the curriculum, they were no significant difference in the analysis of Levene's test of homogeneity. According to the analysis of independent sample t test (See Table 6), it was no significant difference between the gifted girls no matter whether they studied in single-sex girl school or co-educational school. They had much improvement in science learning interesting (From M=3.65, 3.46, and 3.48 to M=4.02, 3.94, and 3.88), science learning motivation (M=3.15 and 3.98 to M=3.40 and 4.13) , even that they felt more difficult in science learning understanding, transferring, and time management (See Table 4).

Table 6. The t-test analysis of science learning interesting, learning motivation, and learning difficulty between two different kinds of schools

The performance after the curriculum	t-test for equality means				
	T	df	Sig.	M Diff.	StD err. Diff.
SLI-TH	-1.550	30	.132	-.458	.296
SLI-VE	-.771	30	.447	-.192	.249
SLI-LA	-.323	30	.749	-.087	.271
SLM-EM	.018	30	.986	.004	.238
SLM-IM	.328	30	.745	.077	.234
SLD-TD	-.812	30	.423	-.230	.284
SLD-UD	-.053	30	.958	-.013	.249
SLD-TRD	-1.164	30	.253	-.263	.225
SLD-TMD	.087	30	.932	.027	.318

4. CONCLUSION & DISCUSSION

STEM encompasses the development of fundamental knowledge and also its application in addressing real-world problems and meeting human needs [11]. Through the implementation of this study, we found that short-term STEM curriculum might not effectively enhance students' scientific interest and career self-efficacy, but it is helpful for them to improve their scientific interest and learning motivation, even though they felt difficult. Therefore, teachers should guide these girls timely. Furthermore, STEM performance curriculums, such as related mechanical or electronic operations and assembly, are more helpful to co-educational girls than to single-sex female students. Teachers should provide enough courses or activities to help them and give them more encouragement, support, and guidance to enhance their self-confidence to learn science.

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