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Micro:bit Robotics Course: Infusing Logical Reasoning and Problem-Solving Ability in Fifth Grade Students Through an Online Group Study System

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Abstract

With rising societal interest in the subject areas of science, technology, engineering, art and mathematics (STEAM), a micro:bit robotics course with an online group study (OGS) system was designed to foster student learning anytime and anywhere. OGS enables the development of a learning environment that combines real-world and digital-world resources, and can enhance the effectiveness of learning among students from a remote area. In this pre- and post-test experiment design, we studied 22 (8 males and 14 females) 5th grade students from a remote area of Taiwan. A *t* test performed before and after the robotics course showed a positive increase in students' proportional reasoning, probabilistic reasoning, and ability to analyze a problem. Results also revealed a gender difference in the association between students' logical reasoning and problem-solving ability.

Keywords: logical reasoning, problem solving, micro:bit robot, gender differences, STEAM

Introduction

The importance of science, technology, engineering, art and mathematics (STEAM) education has been recognized worldwide, as has been the prevalence of online courses and their impact on improving students' logical thinking and problem-solving ability in a digitally-driven information society. Meanwhile, the advancement of science and technology as well as the development of robots have rapidly progressed in recent years. Robotic technologies such as autonomous vehicles, storage robots, and hotel automation operations have gradually infiltrated our everyday lives. New tools and online courses are necessary for the growing needs of developing competencies and skills in the 21st century (Voogt et al., 2013).

The British Broadcasting Corporation (BBC) collaborated with 29 companies and institutions (e.g., Microsoft, Advanced RISC Machine Ltd., Python Software Foundation) to develop an open source, handheld, and programmable embedded system microcomputer. Based on Acorn RISC Machine technology, and called micro:bit, it was designed to help students learn programing and robotics (Micro:bit, n.d.). Research conducted by Sentance et al. (2017) showed that micro:bit was easy for children to use and learn about STEAM. Researchers from King's College London (BBC) found that "90% agree that BBC micro:bit helped to show them that anyone can code" (2017, para. 2).

Programming logic has long been recognized as a tool essential for any business. Thus, teaching students how to code with robots is crucial; it requires that students experience several thinking processes and be introduced to interdisciplinary STEAM learning (Khine, 2017). To achieve this goal, a micro:bit online course helps students build skills in logic and systems thinking, while also engaging them in community discussions and online real-time functions to find better solutions. Moreover, a micro:bit robotics course helps students with self-directed learning through social cues and communication skills in online group discussions (Huang & Wu, 2011). Considering these advantages, this study used the micro:bit in a leading role. This study expected that children would learn and improve their logical reasoning ability from the micro:bit robotics course, which in turn would increase their opportunities to encounter difficulties and problems in everyday life. During daily school learning, the micro:bit robotics course served as an opportunity for students to test their problem-solving abilities.

Logical thinking is a process of transforming abstract emotional ideas into concrete rational concepts, and then using these concepts to judge, make conclusions according to certain logical relationships, and generate new understanding. Logical reasoning ability refers to a psychological process whereby information is converted from the unknown to the known. Logical reasoning ability is an important indicator of cognitive development and intelligence (Siegler, 1991), and is related to complex high-level thinking such as problem solving, social judgment, and criticism (Wright & Dowker, 2002). Roberge and Craven (1982) found that logical reasoning was closely related to mathematics, science, and language ability. Thus, logical reasoning ability can be improved through continuous learning. Although logical reasoning ability is a necessary element in argumentation and a key ability in adapting to future social changes, previous research has found limited evidence of a link between the ability to make logical connections and problem solving (Kuhn, 1991).

Yenilmez et al. (2005) investigated 7th to 12th grade students' logical-thinking ability and the effects of gender and grade level. After reviewing previous research, they found significant differences in gender and grade level between girls and boys. In addition, although a few studies have examined whether the effect of online courses is associated with the development of logical reasoning at the elementary school level (Liu et al., 2015), less knowledge is available with respect to the impact of online courses on the development of logical reasoning in rural areas and/or differences by gender. This study aimed to fill the gap by investigating the effect of the micro:bit robotics course on logical reasoning and problem-solving ability, and whether the effect varied between female and male students in a remote area of Taiwan. The remainder of this paper is organized as follows. First, we present a literature review, then we discuss the experimental design and results. Finally, we present our conclusions and discussion.

Literature Review

Test of Logical Thinking (TOLT)

Piaget and his colleagues conducted research and extensive analysis on the formal reasoning ability of teenagers and adults (Arlin, 1975; Chiappetta, 1976; Farrell, 1969; Lovello, 1961). The items defined in previous research determined the basis of Test of Logical Thinking (TOLT) (Lawson, 1978; Lawson et al., 1979). The TOLT has provided a reliable method to evaluate formal reasoning ability but has also aimed to construct a research tool that can be used for teaching and learning. This method included five valid items from previous studies, namely (a) controlling variables, (b) proportional reasoning, (c) combinatorial reasoning, (d) probabilistic reasoning, and (e) correlational reasoning. These five items have been considered as basic abilities in evaluating mathematics and science courses (Bitner, 1991).

According to Tobin and Capie (1984), evidence showed that TOLT had a high degree of internal consistency, and the validity data was sufficiently diverse to support a group test of formal thinking. In short, TOLT provided a method to precisely measure formal thinking. Furthermore, the resulting data was a useful reference for teachers to examine students' learning effectiveness.

Online Group Study (OGS)

Since the rapid development of network technology, online learning has received a great deal of attention (Lin et al., 2011; Lin et al, 2010); students' online reading behavior has become a subject of theory as well as application for researchers (Liu, 2005; O'Hara & Sellen, 1997). The OGS system, an online reading environment incorporating group study, was designed to provide students with opportunities to read and talk (Yu et al., 2012). Researchers have agreed that reading behaviors differ between digital and print texts (Birkerts, 1994; Bolter & Grusin, 2000).

With the OGS system, students can immediately share their experience of reading e-books with other students within the group. Students can use an online social network for exchanging information with other students (Huang et al., 2013). Additionally, teachers can provide guidance before students read, or during the reading process, within the same online social network. Through reading and discussions within the group, students can share their knowledge, absorb the knowledge of others, improve their reading skills, and achieve meaningful learning experiences (Huang et al., 2011). The purpose of this study was threefold: (a) use the OGS system to facilitate teacher and student reading during group study with the micro:bit robotics course; (b) explore the interrelationships between students' logical reasoning ability and their problem-solving ability after their involvement in the micro:bit robotics course with OGS; and (c) obtain and analyze student feedback after use of the OGS system using the Test of Logical Thinking (TOLT) to measure five models of formal reasoning.

Problem Solving

Problem solving and logical reasoning are two key types of thinking. Thinking, in terms of formal, logical reasoning normally begins to appear at about developmental age 11 or 12 (Flavell, 2007). Axten et al. (1973) proposed a description for the term "problem" when they stated that "to describe continuously his efforts to solve it" (p. 170). After the problem arises, an individual will typically try to solve it, which indicates problem solving in action (Bransford & Stein, 1984). Gagné (1985) proposed that problem solving be seen as a process in which learners find they can combine previously learned rules (e.g., concepts, plans) and apply them to solve a current problem for which they have no direct precedent. Therefore, problem solving is the ability to use old experiences and prior knowledge to detect problems, collect and think about relevant information, develop new methods through inquiry and reasoning, and obtain the answer at the end of the process.

John Dewey, in his book *How We Think,* pointed out that through daily problems or situations, people are forced to think about solutions during the process of learning, which is the process of problem solving (Dewey, 1910). Dewey's problem-solving steps are (a) define the problem, (b) analyze the problem, (c) propose solutions, (d) evaluate the proposed solutions, and (e) select one solution.

In the micro:bit robotics course, students learned logical reasoning; during the process of programming, they encountered difficulties and problems. Therefore, this course also presented an opportunity to test their problem-solving abilities.

Gender Differences

Sungur and Tekkaya (2003) explored the influence of gender and reasoning ability on students' learning achievements and attitudes. According to their results, there was no interaction between gender difference and reasoning ability. Valanides (1996) conducted research with 7th to 9th graders to investigate gender and grade-level differences in five formal reasoning modes from TOLT. Results showed no gender differences. Though students in the higher grades performed better in the proportional reasoning aspect of TOLT. In other research conducted by Valanides (1997) on potential gender differences among 12th graders, results showed that the participants performed better on proportional reasoning and controlling variables. Yenilmez et al. (2005) noted that male students tended to perform better on probabilistic reasoning than did female students. However, in terms of learning achievement, the results were the opposite.

Despite the dearth of research on logical reasoning and gender differences in recent years, the issue of gender differences still exists in STEAM, problem solving, and programing areas. For example, Hacıömeroğlu and Hacıömeroğlu (2017) examined the relationships among gender, spatial ability, logical reasoning ability, and preferred mode of processing; they found no significant differences between the two genders in mode preference and logical reasoning ability. Conradty and Bogner (2018) explored students' creative ability when science, technology, engineering, and math (STEM) was enhanced to become STEAM; gender differences in studies on creativity remain ambiguous. Yurdugül and Aşkar (2013) investigated the differences between gender and general problem-solving skills in development of programming knowledge, but there were no significant gender differences in programming achievement.

Although research on gender differences in logical reasoning has been inconclusive, Jung (2012) found that even though distance education has contributed to widening access to education and reducing the gender disparity in education, there remains a lack of gender-based considerations in Asian distance education. This study assumed the presence of a gender difference in the association between logical reasoning and problem solving, revealed by a possible subgroup variation in relation to the effect of the micro:bit robotics course with OGS.

Method

Participants

The experimental pre- and post-test design aimed to explore the effect of the micro:bit robotics course with OGS on students' logical reasoning and problem-solving ability, and whether this effect varied between male and female students. A total of 22 students in an elementary school in southern Taiwan (8 males and 14 females, with a mean age of 10.6 years) participated in the study. Students had been in contact with computers since the third grade of elementary school. Each student was able to conduct a basic Internet search, do word processing, and demonstrate basic logic programming skills such as Scratch and those developed at code.org.

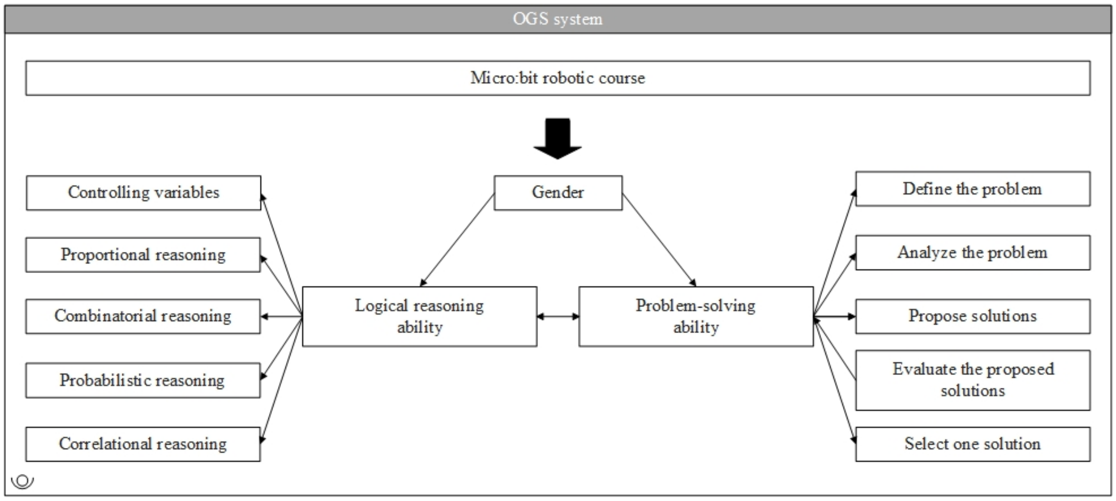
Since the school was in a remote area of Taiwan, this study used the OGS system to teach the micro:bit robotics course, as OGS provided a real-time group study platform and online social network functions. Teachers and students uploaded learning materials to the OGS system, including e-books, slides, videos, animations, and MS-Word documents. Teachers and students joined an online group study, simultaneously studying the learning materials, coding samples, and demonstrations.

Data Collection and Analysis

This study divided the pre-test and post-test measurements into two parts—the logical reasoning ability test and the problem-solving ability test. The detailed experimental framework is shown in Figure 1. The experiment ran for three months, from August 2019 to November 2019. Each class met once per week for 40 minutes each time. After collecting the pre-test and post-test data from TOLT and the problem-solving test, a significance level was set ($a = .05$); we used SPSS (version 22) for two-tail analysis to understand the interrelationships between students' logical reasoning and problem-solving ability after learning with the micro:bit robotics course with OGS.

Figure 1

Experimental Framework



Instruments and Activities

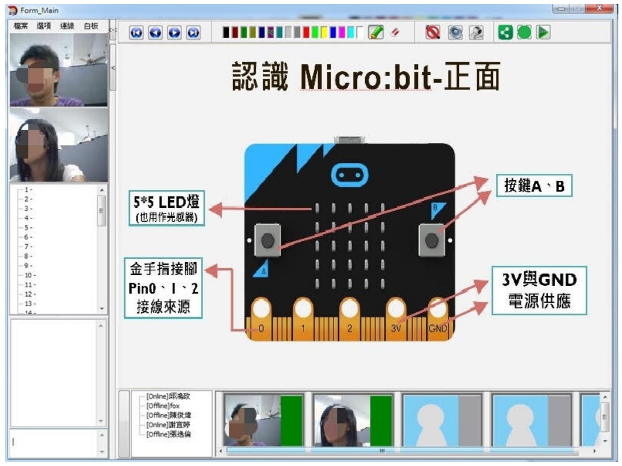
Teachers for the experimental class agreed to use online group study to support their provision of lectures during the semester. The learning materials were uploaded to the online social network for students. The procedure used for the group study was as follows.

Before Group Study

The students were divided into groups. Each group includes at least 2 students In accordance with the course content, the teacher provided e-books and related learning materials about the micro:bit robotics course as shown in Figure 2. A group leader was responsible for the work, including convening the group, discussion, knowledge sharing, and implementation.

Figure 2

Student Activity Before Group Study



During Group Study

During the warm-up activities, the teacher used robot-related news or videos to stimulate students' learning interest based on the e-book's course goals. During the activities, the teacher explained the logical reasoning behind the program code and demonstrated how to work with the micro:bit robot, as shown in Figure 3. During the practice activities, the teacher encouraged students to try coding themselves. If students encountered problems, they were supported in trying to solve the problem. During the activities, the teacher stimulated students' creative thinking through having them write more functional programs and demonstrate the operation of their own robots to other groups on the OGS.

Figure 3

Student Activity During Group Study

After Group Study

The teacher and students shared their experiences about how to solve the problem or modify the code to make the robot work through the online group study system, as shown in Figure 4.

Figure 4

Student Activity After Group Study

Hypothesis and Questionnaires

This study investigated elementary students' logical reasoning ability, problem-solving ability, and gender differences. The following questions guided the study:

1. Did 5th grade students increase their logical reasoning ability after attending the micro:bit robotics course?
2. Did 5th grade students increase their problem-solving ability after attending the micro:bit robotics course?
3. Did the improvement in students' logical reasoning ability after they attended the micro:bit robotics course differ between male and female students?
4. Did the improvement in students' problem-solving ability after they attended the micro:bit robotics course differ between male and female students?
5. Was there a gender difference in the students' performance in logical reasoning ability and problem-solving ability?

Based on the Test of Logical Thinking developed by Tobin and Capie (1984), the logical reasoning questionnaire used in this study aimed to determine students' formal reasoning skills. There were 30 items in the questionnaire to measure controlling variables (items 1 to 6), proportional (items 7 to 12), combinatorial (items 13 to 18), probabilistic (items 19 to 24), and correlational (items 25 to 30) reasoning. Each correct item received 1 point, but wrong and blank answers were given 0 points, for a total of 30 points. The range of test scores was 0 to 30. The developers have demonstrated the psychological characteristics of TOLT. The questionnaire was translated into Chinese with a reliability of 0.76. The pre-test and post-test instruments had the same structure but different content; all characters were text and there were no graphical problems.

The problem-solving ability questionnaire had 10 items that focused on two major questions. Each major question was divided into Dewey's five-step problem-solving process: (a) define the problem (items 1 and 6); (b) analyze the problem (items 2 and 7); (c) propose solutions (items 3 and 8); (d) evaluate the proposed solutions (items 4 and 9); and (e) select one solution (items 5 and 10). Each question was worth 1 point, awarded for the correctness of the answer. Questions 2 and 5 had only one correct answer; questions 1, 3, and 4 had multiple potential answers. There was no upper limit on the overall score; the higher the score, the better the problem-solving ability.

Results

To investigate the effect of a micro:bit course on students' logical reasoning and problem-solving ability, a dependent sample of paired t tests between pre- and post-test was performed. Given the small sample in this study, we also reported the non-parametric of the Wilcoxon signed rank test for the dependent samples t test. In our case, we have an ordinal repeated outcome in the pre-test and post-test with a small sample size (N = 22), which did not fit the assumption of the normal distribution in the outcome. We adopted a common alternative to test the difference when its assumptions were not met.

The results of the students' logical reasoning ability between pre-test and post-test are shown in Table 1. Students' logical reasoning consisted of five measures: (a) controlling variables, (b) proportional reasoning, (c) combinatorial reasoning, (d) probabilistic reasoning, and (e) correlational reasoning. Post-test scores of all five measures were higher than pre-test scores. Among the five measures, the post-test scores of proportional reasoning ($T_{paired\ t-test}$ = 3.167, p = .005) and probabilistic reasoning ($T_{paired\ t-test}$ = 4.743, p = .000) were significantly higher than the pre-test scores. The results of the two-tailed Wilcoxon signed rank test were also significant for proportional reasoning (z = 2.543, p < .05) and probabilistic reasoning (z = 3.476, p < .01). The results indicated that the median of proportional reasoning post-test was significantly higher than the median in the proportional reasoning pre-test. Likewise, the median of probabilistic reasoning post-test was significantly higher than the median in the probabilistic reasoning pre-test. Effect size is reported in column eight of Table 1. Cohen's d of proportional reasoning was .79 and Cohen's d of the probabilistic reasoning was 1.32. In the total score for the five measures, the results indicated that the difference between pre-test and post-test scores was statistically significant ($T_{paired\ t-test}$ = 3.594, p = .002) and the two-tailed Wilcoxon signed rank test (z = 2.801, p<.01). Cohen's d of the total score was .80. With respect to the standard deviation, five measures of logical reasoning in the post-tests were larger than those in the pre-test, indicating that after the implementation of the micro:bit robot course, the differences in the scores of each aspect became larger. In short, the micro:bit robot course improved the students' ability in proportional reasoning, probabilistic reasoning, and the total scores of logical reasoning.

Table 1

Mean Difference of Logical Reasoning Ability for the Micro:bit Robotics Course in the Pre-Test and Post-Test

Logical Reasoning ability	Pre-Test		Post-Test		Diff.		p-value	Wilcoxon rank test [b]		ES [a]
	Mean	*SD*	Mean	*SD*						
Controlling variables	3.45	0.67	3.73	0.55	0.27		0.56	1.897		
Proportional reasoning	2.55	0.74	3.27	0.98	0.73	*	.005	2.543	*	.79
Combinatorial reasoning	5.95	1.53	6.32	2.23	0.36		.474	.964		
Probabilistic reasoning	1.55	0.86	3.00	1.20	1.45	***	.000	3.476	**	1.32
Correlational reasoning	2.45	0.80	3.23	1.80	0.77		.121	1.486		
Total scores (0–30)	15.95	2.36	19.55	5.28	3.59	**	.002	2.801	**	.80

Note. Total sample N = 22.

*** $p < .001$, ** $p < .01$, * $p < .05$, two-tailed paired t test.

[a.] Cohen's d was reported to measure the effect size. Cohen (1988) defined the magnitude of the effect as small (d = 0.2), medium (d = 0.5), or large (d = 0.8).

[b.] The Wilcoxon signed rank test was reported to confirm the results of the dependent samples t test when the assumption of normality did not fit.

The results for problem-solving ability between the pre-test and post-test are shown in Table 2. Students' problem-solving ability consisted of five measures: (a) define the problem, (b) analyze the problem, (c) propose solutions, (d) evaluate the proposed solutions, and (e) select one solution. Post-test scores of all five measures were higher than pre-test scores. Among the five measures, only the post-test of "analyze the problem" ($T_{paired\ t-test}$ = 2.614, p = .016) was significantly higher than the pre-test. We applied the two-tailed Wilcoxon signed rank test and also found a similar significance for "analyze the problem" and the total scores for problem solving. In addition to each measure of problem solving, the total scores for problem solving also showed that the post-test was significantly higher than the pretest scores ($T_{paired\ t-test}$ = 2.184, p = .040). With respect to the standard deviation, five measures of problem-solving ability in the post-test were larger than those in the pre-test, indicating that after the implementation of the micro:bit robotics course, the differences in the scores for each aspect became larger. In short, the micro:bit robotics course improved students' ability to analyze the problem, as well as problem-solving ability as a total score.

Table 2

Mean Difference of Problem-Solving Ability for the Micro:bit Robotics Course in the Pre-Test and Post-Test

Problem-solving ability	Pre-Test		Post-Test		Diff.		P-value	Wilcoxon rank test [b]		ES [a]
	Mean	SD	Mean	SD						
Define the problem	3.41	1.79	4.09	1.74	0.68		.061	.359		
Analyze the problem	1.00	0.82	1.41	0.80	0.41	*	.016	.038	*	0.5
Propose a solution	1.55	1.44	1.91	1.72	0.36		.401	.804		
Evaluate the proposed solutions	2.82	1.05	3.27	2.29	0.45		.381	1.000		
Select one solution	2.23	0.75	2.68	1.52	0.45		.125	.238		
Total assessment score	11.00	4.38	13.36	6.59	2.36	*	.040	.189	*	0.39

Note. Total sample $N = 22$.

* $p < .05$, two-tailed paired t test.

[a.] Cohen's *d* was reported to measure the effect size.

[b.] The Wilcoxon signed rank test was reported to confirm the results of the dependent samples *t* test when the assumption of normality did not fit.

Taking gender as the self-variant, the changed scores for logical reasoning ability from pre-test to post-testwas the dependent variable; analysis of the independent two sample *t* test explored the gender differences in logical reasoning ability as shown in Table 3. Before analyzing the gender differences in changes between pre-test and post-test, we investigated the homogeneity hypothesis in the variance of the male and female sample across all measures of logical reasoning. The Levene test value of the variance was found to be an insignificant indication of the unequal variance between the male and female sample across all measures. Therefore, we can assume there was equal variance between male and female students across all measures of the logical reasoning ability.

Table 3

Gender Differences in Logical Reasoning Ability After Completing the Micro:bit Robotics Course

Panel A: Pre-Test	Male (n = 8)				Female (n = 14)					ΔMale-Female
	Pre-Test		Post-Test		Pre-Test		Post-Test			*t* Test
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*		
Controlling variables	3.50	0.76	3.61	0.52	3.43	0.65	3.79	0.58		-0.72
Proportional reasoning	2.25	0.71	3.00	0.76	2.71	0.73	3.43	1.09		-0.98
Combinatorial reasoning	5.75	1.91	5.13	2.03	6.07	1.33	7.00	0.56	**	-3.28
Probabilistic reasoning	1.75	1.16	2.75	1.16	1.43	0.65	3.14	1.23		-0.73
Correlational reasoning	2.25	0.89	2.75	1.98	2.57	0.76	3.50	1.70		-0.93
Total assessment score (0–30)	15.50	3.21	17.25	5.12	16.21	1.81	20.86	5.08		-1.59

** $p < .01$, two-tailed *t* tests.

Female students reported a lower level of controlling variables and probabilistic reasoning in the pre-test, but their gains from pre-test to post-test score were higher than were male students' in the level of controlling variables and probabilistic reasoning. From the pre-test to post-test, female students improved by 0.36 points for the controlling variables and 1.71 points for probabilistic reasoning, indicating that the female students' progress on the level of controlling variables and probabilistic reasoning was greater than was the male students. To further confirm whether the progress (changed scores) differed between male and female students, we employed the two-sample *t* test. The results showed that the differences did not reach statistical significance.

Female students reported a higher level of proportional reasoning, combinatorial reasoning, and correlational reasoning in both the pre-test and post-test. We ran the two-sample *t* test to examine whether the changed scores differed between male and female students. The results showed that there was a significant gender difference in the changed scores for combinatorial reasoning. However, we did not find the same significance in the two-tailed Wilcoxon signed rank test. This may indicate the gender difference in the combinatorial reasoning was due to the small sample.

The results of the two independent sample *t* tests on the changed scores for problem-solving ability are shown in Table 4. We first checked the Levene test value of the variance and found that there was no significant indication of unequal variance between the male and female sample across all measures of problem-solving ability. Therefore, we can assume there was equal variance between male and female students across all measures of problem-solving ability. We ran the two-sample *t* test to examine whether the changed scores differed between male and female students. The results showed that there was a significant gender difference in the changed scores for selecting one solution, and this gender difference was confirmed in the two-tailed Wilcoxon signed rank test (z = 2.561, p < .05).

Table 4

Gender Differences in Problem-Solving Ability After Completing the Micro:bit Robotics Course

Problem-solving ability	Male				Female					ΔMale-Female
	Pre-Test		Post-Test		Pre-Test		Post-Test			*t* Test
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*		
Define the problem	2.38	1.60	3.63	2.00	4.00	1.66	4.36	1.60		1.265
Analyze the problem	0.88	0.83	1.13	0.99	1.07	0.83	1.57	0.65		-0.761
Propose solution	1.00	1.07	1.25	1.28	1.86	1.56	2.29	1.86		-0.198
Evaluate the proposed solutions	2.50	0.93	2.75	2.87	3.00	1.11	3.57	1.95		-0.297
Select one solution	2.00	0.76	1.63	1.85	2.36	0.74	3.29	0.91	*	-2.451
Total assessment score	8.75	3.37	10.38	8.05	12.29	4.46	15.07	5.17		-0.507

* p < .05, two-tailed *t* tests.

To further examine whether male students had significantly higher correlation between logistical reasoning and problem solving than did female students, we used the Fisher r-to-z transformation to assess the significance of the difference between two correlation coefficients in two independent samples (Preacher, 2002; http://quantpsy.org/corrtest/corrtest.htm). Our results in Table 5 show that male students (r = .926) had significantly higher correlation between logistic reasoning and problem solving than did females (r = .501) in the post-test (z = 2.00, p = .045). The effect size for the difference between two correlations was 1.079.

Table 5

Correlation Between Logistic Reasoning Ability and Problem-Solving Ability

Population	Variable	1		2		3		4
Male	1. Logistic reasoning pre-test	1						
	2. Logistic reasoning post-test	.278		1				
	3. Problem solving pre-test	.436		.749	*	1		
	4. Problem solving post-test	.329		**.926**	***	.830	*	1
Female	1. Logistic reasoning pre-test	1						
	2. Logistic reasoning post-test	.633	*	1				
	3. Problem solving pre-test	.737	**	.701	**	1		
	4. Problem solving post-test	.625	*	**.501**		.483		1

Note. Full sample N = 22, male sample n = 8, female sample n = 14.
*** $p < .001$. ** $p < .01$. * $p < .05$.

According to Tables 1 to 5, we have made the following conclusions about our hypotheses:

1. Attending students had higher post-test scores on the logical reasoning test, indicating that the micro:bit robot course increased the students' logical reasoning ability.

2. Attending students had higher post-test scores on the problem solving test, indicating that the micro:bit robot course increased the students' problem-solving ability.

3. There were equal variances between male and female students across all measures of logical reasoning ability; we did not find strong evidence of gender difference in the changed scores for combinatorial reasoning.

4. There was no gender difference between the mean scores of male and female students in problem-solving abilities related to the five problem-solving steps, but there was a significant gender difference in the changed scores for selecting one solution.

5. Male students had a significantly positive correlation between logistical reasoning and problem solving on the post-test. We found no evidence of a positive correlation between logistical reasoning and problem solving on female students' post-tests.

Conclusions and Discussion

People mistakenly assume that the ultimate goal of science and technology courses is to force children to grow and prepare to be scientists, mathematicians, and engineers (Sullivan, Strawhacker, &Bers, 2017). In contrast, STEAM education aims to provide children with systematic themes and experiences suitable for them during their school years and beyond (Bers, 2012). From this point of view, the results of this study reported the effect of a micro:bit robotics course with OGS on logical reasoning ability and problem-solving ability, as well as gender differences among fifth graders. There are two perspectives from which one can assess the value of these results.

From the first perspective, knowing students' weaknesses in logical reasoning and problem-solving skills is critical in order for teachers to predict students' difficulties and then modify their teaching strategies to make concepts easier to understand. In this study, the micro:bit robotics course with OGS greatly improved participants' logical reasoning ability. Results indicate that the robotics course was helpful for students. Throughout the course, students encountered many difficulties, such as the robot not being able to move as expected due to incorrect programming, hardware problems, or human factors. Even so, students were encouraged to find and solve problems by redesigning programming strategies or changing hardware, thereby facilitating the development of their problem-solving abilities. Teachers can also evaluate students' logical reasoning problems by understanding the reasoning skills that students currently adopt and using these as a reference to modify teaching strategies.

Moreover, comparing the logical reasoning performance of male and female students, there were equal variances across all measures of logical reasoning ability, but there were gender differences on the changed scores for combinatorial reasoning when we applied the paired *t* test. However, we did not find similar gender difference when we applied the two-tailed Wilcoxon signed rank test. This result indicates the gender difference in combinatorial reasoning is due to the small sample and violation of the normality assumption. Furthermore, when comparing the problem-solving performance of male and female students, there was no gender difference between male and females, but there a significant gender difference in the changed scores for selecting one solution. Thus, despite no differences between males and females, we can see that logical reasoning may influence the problem-solving methods of males and females. Meanwhile, male students had a significantly positive correlation between logistical reasoning and problem solving on the post-test. It appears that gender differences still play a role in students' logistical reasoning and problem-solving abilities.

Gender differences in terms of social interaction styles occur in the traditional classroom, such as the notion that boys are more likely than girls to participate in class discussion. As with physical differences, however, gendered social differences may not occur uniformly for all boys and girls. The performance of boys and girls between traditional classrooms and online courses may be very different. From an equity-in-learning perspective, the future goal of this study is to expand with a larger sample size and design more effective intervention strategies based on gender differences, and thereby explore social differences between boys and girls in online courses.

Our effect size ranged from moderate to large, which is unusual. Although the effect sizes seem to be large, this is probably due to our small sample size. We need to be cautious when interpreting effect size and reporting this as our final discovery. In future, we may be able to provide more effective evidence if we have larger sample.

While the results of this study are promising, we used a small sample and therefore results should not be interpreted as a general randomization pre- and post-test design for the 5th grade student population. This is our first step in developing a field test of the micro:bit robotics course with OGS as an approach that may improve students' logical thinking and problem-solving ability. Our vision is to incorporate the micro:bit robotics course as part of a strategy of having coding teacher specialists operating in low-income schools in rural areas where STEAM resources are limited. We argue that these types of online learning experiences can be particularly useful and effective as a support tool for elementary students' lack of family and school resources about STEAM.

Due to the prevalence of the COVID-19, except for Taiwan and a few countries that are still keeping schools open, almost all countries in the world have closed their educational institutions. For millions of learners, learning has been forcibly interrupted (United Nations Educational Scientific and Cultural Organization [UNESCO], n.d.). In order to minimize the impact of interrupted education and integrate continuous learning, teachers should provide multiple learning environments or backup plans for teaching to improve their teaching in order to meet rapidly changing needs. At the same time, the application of distance education has become a very hot topic and has received considerable attention.

Deeper and wider implementation of distance education needs to be considered. In order to make distance education more meaningful, teachers need to help students choose learning content and attend to their learning progress. Meanwhile, based on the theory proposed by Remmele and Holthaus (2013), the more widespread the use of digital learning, the less gender differences occur among students. Distance education will need to be developed as an open and flexible form of instruction that can be adjusted to address students' requirements (Peters, 2000). Teachers who can follow these guidelines and be aware of these differences can then design appropriate e-learning lessons. Moreover, with continued research and reflection, distance education will become a new self-learning and student-oriented tool for a new generation.

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