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English Medium Instruction for Electrical Engineering Education: A Focus on Physical Computing*

AI-JOU PAN
Department of Engineering Sciences, National Cheng Kung University, Tainan, Taiwan. E-mail: n98101038@gs.ncku.edu.tw

CHIN-FENG LAI
Department of Engineering Sciences, National Cheng Kung University, Tainan, Taiwan. E-mail: cinfon@ieee.org

CHUN-CH HSU
Department of Vehicle Engineering, National Pingtung University of Science and Technology, Pingtung, Taiwan.
E-mail: maker.npust@mail.npust.edu.tw

PAO-NAN CHOU**
Graduate Institute of Technological and Vocational Education, National Pingtung University of Science and Technology, Pingtung, Taiwan. E-mail: pnchou@mail.npust.edu.tw

The aim of this study was to investigate the effect of the English Medium Instruction (EMI) model on elementary school students' engineering learning and English proficiency and to examine their EMI learning experiences. Accordingly, a true experimental design with a pretest and posttest was adopted. Thirty elementary school students participating in a winter camp were recruited and randomly assigned to two experimental groups: EMI and semi-EMI. The students in the EMI group received engineering instruction delivered in English; those in the semi-EMI group received only English-based engineering learning materials, but the lectures were in Chinese. The quantitative results revealed that the students' acquisition of engineering (programming and electrical engineering) content knowledge and their English proficiency were significantly improved under the EMI model. In addition, the qualitative results indicated that positive learning attitudes might enable students to excel in EMI learning scenarios.

Keywords: English Medium Instruction; electrical engineering; physical computing; experimental study; educational reform; university social responsibility

1. Introduction

Among Asian countries, Hong Kong and Singapore have implemented English Medium Instruction (EMI) in K–6 schools for a long period. Following this trend, the National Development Council of Taiwan recently announced a blueprint for developing a bilingual nation by 2030 in an effort to increase national competitiveness [1]. The core concept of this national policy is to integrate the EMI model into various academic disciplines in K–16 schools, meaning that school teachers must deliver courses in English for nonnative English speakers.

Prior to the implementation of the national bilingual policy, EMI learning activities in Taiwan were generally reserved for higher education institutions, and EMI courses were rarely seen in primary and secondary schools (except for American or bilingual private schools). In college, EMI courses were often offered by enthusiastic instructors who attempted to transform students' learning experiences. Chang [2] conducted a survey and reported that Taiwanese college students did not express any negative attitudes toward EMI subject courses. Hsieh and Kang [3] conducted an experimental study and revealed that engineering students in an EMI group showed higher learning motivation than did their counterparts.

In response to the new bilingual policy, a research team at National Pingtung University of Science and Technology (NPUST) proposed a university social responsibility (USR) project entitled "EMI Engineering in Elementary" (3E), the aim of which was to advance the EMI learning experiences of engineering students and provide a valuable opportunity for K–6 students to immerse themselves in an EMI learning environment. The 3E project was conducted from 2020 to 2021 and focused on only one local elementary school.

During the project implementation, several engineering students who had previously enrolled in a physical computing course were recruited to receive intensive EMI instruction. Upon the completion of the training program, the students were required to design and develop an EMI winter camp for elementary school students. The overarching goal of the camp was to enable nonnative English speakers to learn electrical engineering concepts in English and to enrich their STEM learning experiences [4].

** Corresponding author.

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The student-led EMI winter camp focused on one physical computing domain in electrical engineering, namely block programming of the Micro:Bit electronic board. The engineering content in the camp was customized for elementary school students in accordance with the national science and technology curriculum standards [5]. The present study was conducted to investigate the effect of the EMI model on elementary school students' acquisition of engineering concepts and English proficiency and to evaluate the students' EMI learning experiences. Specifically, the study attempted to answer two major research questions:

- Did EMI model increase elementary school students' knowledge of engineering concepts and English skills?
- What were the elementary school students' responses regarding their EMI learning experiences?

2. EMI Model

EMI has a strong basis on two educational policies: Content-Based Instruction (CBI) in North America and Content and Language Integrated Learning (CLIL) in Europe. After a systematic analysis of 30 CBI studies, Dupuy [6] outlined that the CBI model might increase students' foreign language proficiency, content knowledge, learning confidence, and learning motivation. By extensively reviewing the CLIL policy, Coleman [7] proposed that CLIL has the same learning benefits as CBI; however, CLIL emphasizes two positive learning outcomes: content knowledge development and foreign language ability.

In general, EMI shares similar characteristics with CBI and CLIL, but EMI focuses on the English language. Chang [2] indicated that the ultimate goal of EMI adoption is to force educational institutions to move toward academic internationalization, the added value of which is the development of the internationalization of talented students. Furthermore, Coleman [7] specified some factors associated with EMI policy implementation in schools: global mobility of students and staff, recruitment of international students, international cooperation of academic resources, and career development opportunities for students. Table 1 presents a summary of the main factors associated with EMI integration into the classroom in non-English-speaking countries.

Macaro et al. [13] empirical studies on EMI and indicated that most EMI learning activities tend to appear in higher education institutions worldwide. Nevertheless, they noted that findings of the analyzed studies were contradictory; specifically, some of the analyzed studies reported that EMI produced positive learning outcomes, whereas others indicated EMI to be an unnecessary learning approach. For example, Hsieh and Kang [3] compared EMI and non-EMI civil engineering classes for two consecutive semesters and found an improvement in English skills in the EMI classes; similar findings have also been revealed by Wu [14] and Yang [15]. By contrast, Joe and Lee [16] examined the learning outcomes of EMI and non-EMI medical students and revealed no significant differences in their English proficiency or content knowledge. According to Kilickaya [17], college instructors perceived that only the native language might enhance students' content knowledge acquisition.

3. Research Method

3.1 Research Design

This study adopted a true experimental design with a pretest and posttest to investigate the effect of the EMI model on students' content knowledge acquisition and English proficiency. The study recruited elementary school students participating in a winter camp; in this camp, the students were randomly assigned to two experimental groups: EMI and semi-EMI groups. The students in the EMI group received engineering instruction delivered in English; those in the semi-EMI group received only English-based engineering learning materials, but the lectures were delivered in Chinese. Table 2 presents the experimental design used in this study.

Table 1. Factors Associated with EMI Adoption in non-English-Speaking Countries

Source	Country	Factors for EMI Adoption
Jensen & Thogersen [8]	Demark	1. Recruitment of international students 2. Career development of students
Klan [9]	Pakistan	1. Country modernization 2. Cultural progress
Earls [10]	Germany	1. Internationalization 2. Career development of students
Byun et al. [11]	Korean	1. Career development of students 2. Bozdogan & Karlidag [12]
	Turkey	1. Career development of students 2. English proficiency (internationalization)

Table 2. Experimental Design Used in the Study

Group	Pretest	Intervention	Posttest
Experiment: EMI	O_1 O_5 O_9	X	O_3 O_7 O_{11}
Control: Semi-EMI	O_2 O_6 O_{10}		O_4 O_8 O_{12}

O_1, O_2: Programming pretest. O_3, O_4: Programming posttest.
O_5, O_6: Electrical engineering pretest. O_7, O_8: Electrical engineering posttest.
O_9, O_{10}: English pretest. O_{11}, O_{12}: English posttest.

In the experimental design, the dependent variables were three types of tests: programming, engineering, and English tests. The independent variable was the type of instruction intervention (EMI vs. semi-EMI). At the beginning of the winter camp, all students received the three tests as pretests. On the final day of the camp, the three tests with different item numbers were administered to all students as posttests.

In addition to the quantitative research, this study adopted a focus interview protocol [18] to qualitatively record the students' EMI learning experiences. After the completion of the winter camp, some students were invited to participate in a 1-hour discussion forum in which the research team facilitated students to share their opinions on the implementation of the EMI learning activities. The collected qualitative data also served as another resource to support the quantitative findings in the educational experiment.

3.2 *Research Participants*

The study adopted a purposeful sampling method [19]. Students were selected from a public elementary school in Pingtung County, Taiwan. After 1 month of the research campaign, 30 sixth graders were recruited to participate in the EMI winter camp. Prior to the study, the students had basic English skills and Scratch programming experience. Because four students dropped out in the middle of the experiment, the ratio of students between the two experimental groups (EMI: 15; semi-EMI: 11) was not balanced.

3.3 *Outcome Measurements*

1. Programming test: A criterion test regarding block programming was developed to measure the students' understanding of the programming syntax used in the Micro:Bit board. To ensure the test's validity, three field experts were invited to review the test content. Additionally, a pilot study revealed that the reliability coefficient of the measurement was 0.82. The final version of the test contained 20 multiple-choice questions. Fig. 1 displays an example of the programming test.
2. Electrical engineering test: A test was developed to assess the students' understanding of basic electrical engineering concepts. The focus of the test was the structure on the Micro:Bit board attached with an extended electronic device. The test was presented in 10 matching questions. The students were required to choose an appropriate electronic item to match the test description. The test was reviewed by three field experts to ensure its content validity. A pilot test revealed that the reliability coefficient of the test was 0.85. Fig. 2 illustrates an example of the electrical engineering test.
3. English test: An achievement test with 20 multiple-choice questions was developed to measure the students' English proficiency., on the basis of the grade level of the students, the research team selected appropriate test items from a national English test bank. Subsequently, the test items were modified to fit the physical computing scenario in the study. The final version of the test was reviewed by three elementary school English teachers. A pilot study revealed that the reliability coefficient of the test was 0.89. Fig. 3 presents an example of the English test.

3.4 *Physical Computing Tool*

In the winter camp, the Micro:Bit board with the robot car kit was used for educational training in physical computing. This research tool enables elementary school students to use a block programming language (Microsoft MakeCode) to control

1. In order to display "Hello", what kind of command should you use?
(A) basic (B) music (C) loop (D) logic
2. After the micro:bit program is downloaded from the makecode website, what is the. file extension of the program? (A)hex (B)doc (C)odp (D)jpg

Fig. 1. Programming test example.

Please determine the function of the electronic component of the follows:
A. buzzer B. ultrasound C. IR line sensor D. battery indicator
E. switch on/off F. RGB LED G. motor

Fig. 2. Electrical engineering test example.

Please determine the function of the electronic component of the follows:
A. buzzer B. ultrasound C. IR line sensor D. battery indicator
E. switch on/off F. RGB LED G. motor

Fig. 3. English test example.

Table 3. Learning Units of the 5-Day Winter Camp

Unit	Learning Theme	Electrical Engineering Knowledge
1	Micro:Bit and Robot Kit Orientation	Electronic Board
2	Robot walking	Motors
3	Color show	RGB LED module
4	Color guessing show	Color detecting sensors
5	Music performance	Buzzer and Buttons
6	Automatic car	Ultrasonic sensors
7	Remote control car	Infrared controller
8	Line following race	Line patrol sensors

electronic sensors such as color or ultrasonic-wave-detecting sensors. Once students completed the coding projects, programming files downloaded into the board yielded various movements of the robot car.

3.5 Engineering Instructional Procedure

A group of engineering students who had enrolled in a physical computing course (non-EMI format) were invited to the organizing committee of the winter camp. During the course, the college students gained experience in using Python programming to control the Micro:Bit board. The design and development of the winter camp lasted for one semester. The students were required to undergo weekly EMI training and to develop learning materials for the camp.

A 5-day winter camp was implemented in a public elementary school in Taiwan. Each day, all participating children took part in a 3-hour engineering learning activity (morning session: EMI group; afternoon session: semi-EMI group). The same instructor (engineering student) taught the two groups of students. The teaching procedure was based on the three-stage engineering design framework proposed by Chou [20]: copy, modify, and create. Table 3 presents a summary of the learning units of the winter camp.

4. Results and Discussion

4.1 Elementary Students' Content Knowledge of Programming and Engineering and English Skills

Tables 4–6 present the results of a t test for the three outcome measurements, revealing that the students' performance improved in both experimental groups for all tests. None of the students had experience using the block programming language (MakeCode in Micro:Bit). However, the students in the EMI

Table 4. Results of t Test for Programming Content Knowledge

	Mean (S.D.)		**t-test**	
	Pretest	**Posttest**	***t***	***p***
Experiment (EMI)	0(0)	53.30(15.19)	–13.59	0.00**
Control (Semi-EMI)	0(0)	45.91(21.66)	–7.03	0.00**

**$p < 0.01$.

Table 5. Results of t Test for Engineering Content Knowledge

	Mean (S.D.)		**t-test**	
	Pretest	**Posttest**	***t***	***p***
Experiment (EMI)	0(0)	40.00(15.58)	–9.94	0.00**
Control (Semi-EMI)	0(0)	17.72(9.84)	–7.03	0.00**

**$p < 0.01$.

Table 6. Results of t Test for English Skills

	Mean (S.D.)		t-test	
	Pretest	**Posttest**	***t***	***p***
Experiment (EMI)	23.2(10.71)	76.67(8.60)	–26.06	0.00**
Control (Semi-EMI)	30(11.70)	57.09(19.93)	–4.37	0.00**

**$p < 0.01$.

Table 7. Results of ANCOVA for Programming Content Knowledge

Source	TypeIII *SS*	*df*	*MS*	*F*	*p*	Cohen's d
Instruction method	1741.81	1	1741.81	6.06	0.02*	0.62
Errors	6615.37	23	287.63			
Total	8357.18	24	2029.44			

*$p < 0.05$ (EMI: M = 53.33, S.D. = 15.20; Semi-EMI: M = 41.37, S.D. = 22.92).

Table 8. Results of ANCOVA for Engineering Content Knowledge

Source	TypeIII *SS*	*df*	*MS*	*F*	*p*	Cohen's d
Instruction method	3842.97	1	3842.97	24.75	0.00**	1.71
Errors	3570.85	23	155.25			
Total	7413.82	24	3998.22			

**$p < 0.01$ (EMI: M = 40, S.D. = 15.58; Semi-EMI: M = 17.72, S.D. = 9.84).

Table 9. Results of ANCOVA for English Skills

Source	TypeIII *SS*	*df*	*MS*	*F*	*p*	Cohen's d
Instruction method	2982.11	1	2982.11	16.16	0.00**	1.29
Errors	4243.69	23	184.51			
Total	7225.8	24	3166.62			

**$p < 0.01$ (EMI: M = 76.67, S.D. = 8.06; Semi-EMI: M = 57.09, S.D. = 19.93).

group exhibited greater improvements in programming content knowledge (EMI: t = 13.59; semi-EMI: t = 7.03), engineering content knowledge (EMI: t = 9.94; semi-EMI: t = 7.03), and English skills (EMI: t = 26.06; semi-EMI: t = 4.37) than did their counterparts.

After the effect of the pretest was excluded, an analysis of covariance (ANCOVA) was conducted for the three outcome measurements. Tables 7–9 present the ANCOVA results, indicating that the students in the EMI group outperformed those in the semi-EMI group. The students in the EMI group exhibited significant improvements in programming content knowledge ($F = 6.06$, $p < 0.05$), electrical engineering content knowledge ($F = 24.75$, $p < 0.01$), and English skills ($F = 16.16$, $p < 0.01$). In addition, according to Cohen's standard [21], a large effect size (>0.8) was observed for the students' engineering (Cohen's $d = 1.71$) and English (Cohen's $d = 1.29$) learning performance.

4.2 Responses of Elementary Students to EMI Learning Experiences

Table 10 presents a summary of the results of the focus interview. The students' perceptions of EMI learning could be categorized into three themes: learning attention, learning adjustment, and new experience. Overall, the students' attitudes toward EMI learning experiences remained positive, although some challenging tasks were identified in class.

4.3 Discussion

After a 5-day EMI training camp, all participating students exhibited improvements in the three types of learning outcomes, regardless of the experimental group they were in. However, the students in the EMI group outperformed those in the semi-EMI group. After the effect of the pretest was excluded, the students in the EMI group still demonstrated improvements in programming and engineering content knowledge and English skills. Therefore, the results of this study support the findings of previous studies [3, 14, 15] that have demonstrated that the EMI model might advance students' learning experiences, particularly their professional content knowledge and English skills.

The qualitative findings of this study might provide an in-depth insight into how students engage in EMI learning. In the theme of learning attention, the students forced themselves to fully immerse in the teaching scenario to avoid missing information imparted by the instructor. In the theme of learning adjustment, the students adapted

Table 10. Results of the Focus Interview

Theme	Representative Responses
Learning attention	"Because the class was delivered in English, I had to pay attention to the class all the time. I could not miss what the instructor was saying, not even for a brief moment." "I was afraid that I would not understand the lessons. So, I fully focused on what the instructor said." "Compared with the Chinese-based classes, the EMI class required intense focus."
Learning adjustment	"To tell the truth, I could not fully understand what the instructor said the first two days. But, when I picked up the tone of the instructor, the learning tasks became much easier." "If there was a break, I would ask my classmates some questions to cover what I missed in class. But, a few classes later, I found that I could keep pace with what the instructor said." "I would raise my hand when I missed something in class. But I found this happened only on the first two days. When I became adjusted to the class schedule, I could easily comprehend the EMI class."
Learning experience	"I never took an EMI class before. It was a cool learning experience." "Although it was challenging for me, this new learning experience forced me to grow a lot." "I liked to code. It was my first time learning to program under the EMI model. It was such a good experience to learn programming and English at the same time."

to the teaching style of the instructor in order to effectively comprehend the class material. In the theme of learning experience, the students viewed EMI as a learning adventure. Overall, a high degree of attention and positive attitudes toward learning adjustment and experiences might explain the significant improvements in learning outcomes observed in the EMI group.

This study has some limitations that can be addressed in future studies. First, the research was conducted in a one-shot format (5-day schedule). Whether students could exhibit active learning behaviors for a longer period (1 month) warrants further investigation. Second, the age of the instructor (college student) at the winter camp was younger than that of average school teachers; hence, the energetic teaching style of the instructor might have influenced the students' willingness to learn electrical engineering concepts. Future studies may examine the learning behaviors of students by integrating the EMI model into traditional science classes. Finally, the hands-on engineering learning approach used in this study tends to be attractive to elementary students. Future studies may analyze the differences in students' learning motivation when the EMI model is incorporated into traditional engineering lectures. Because of the present study's design, generalizing its findings to other research scenarios may be difficult.

5. Conclusion

This study confirmed the effect of the EMI model on elementary school students' acquisition of engineering (programming and electrical engineering) content knowledge and improvement in English proficiency. The quantitative findings indicate that the EMI model enabled students to achieve improved learning outcomes. Moreover, the qualitative findings reveal that the EMI teaching scenario provided a novel learning experience in which students constantly adjusted to the teaching style of the instructor and paid full attention to the lecture. In summary, the results of this study suggest that EMI engineering teaching may potentially present a new learning paradigm for nonnative English speakers.

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Ai-Jou Pan is a doctoral student at National Cheng Kung University. She is a licensed high school teacher. She was a co-investigator in the EMI project.

Chin-Feng Lai is a Professor of Engineering Sciences at National Cheng Kung University. Dr. Lai was a content expert on the learning content of electrical engineering in the EMI project.

Chun-Ch Hsu is a college student at National Pingtung University of Science and Technology, Taiwan. He was a class leader in the EMI project.

Pao-Nan Chou is a Professor of Technological and Vocational Education and a Director of Smart Media Research Center at National Pingtung University of Science and Technology, Taiwan. Dr. Chou was a principal investigator in the EMI project.