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PAPER

Flipped Classroom Mobile Learning Model and Its Application to Enhance Digital Intelligence Quotient among Secondary Students

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ABSTRACT

Digital intelligence quotient (DQ) is an essential skill for becoming a digital citizen. In Thailand, the development of DQ is a key policy initiative for youth development. Using mobile applications in a flipped classroom (FC) setting enhances learning outcomes and fosters the development of critical skills. This paper proposes a mobile application integrated with a FC model to improve secondary education students' DQ. The study utilized an experimental research design with a one-group pretest-posttest approach to compare students' DQ, analyzed using a paired sample t-test, and assessed student satisfaction. The sample consisted of 60 lower secondary school students under Thailand's Nakhon Pathom Secondary Education Service Area Office. The research findings are as follows: 1) The developed learning model was rated as highly appropriate; 2) The content and technical quality of the FC mobile application was rated very good; 3) Students' DQ significantly improved after using the application, with a statistical significance level of 0.05. Among the eight sub-skills, screen time management showed the highest improvement; and 4) Student satisfaction with the learning model was at the highest level. Based on these findings, the developed model can enhance students' DQ and is adaptable for other audiences requiring digital navigation skills, making the results relevant to broader educational objectives beyond traditional coursework.

KEYWORDS

mobile application, flipped classroom, digital intelligence quotient

1 INTRODUCTION

The Thai National Education Plan envisions that "All Thais are educated and learn throughout their lives with quality and live happily in line with the philosophy of the sufficiency economy and the transformation of the 21st-century world" [1]. Information and communication technologies play a critical role in communication, interaction, business transactions, trading, and social networking. Individuals who

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actively participate in the digital society are referred to as digital citizens. Digital citizenship is essential in the online world, as positive digital citizenship behaviors contribute to a safer and more harmonious online environment.

A key attribute of digital citizenship is the digital intelligence quotient (DQ), which refers to a set of social, emotional, and cognitive abilities that enable individuals to navigate and adapt to the challenges of digital life. DQ encompasses the knowledge, skills, attitudes, and values necessary to function effectively as members of the online community. According to a survey conducted by the DQ Institute, in collaboration with the Digital Economy Promotion Agency (DEPA), Ministry of Digital Economy and Society, and Office of the Basic Education Commission (OBEC), under the #DQEveryChild project [2], 60% of Thai children aged 8–12 years are at risk from online threats. This figure is slightly above the global average of 56% across 29 countries. The online threats identified in the survey include cyberbullying, being lured by strangers via social media, gaming addiction, exposure to pornography, downloading sexually explicit content, and engaging in inappropriate conversations with strangers online.

The increasing integration of digital technologies into daily life, particularly for children. As digital challenges such as cyberbullying, online privacy concerns, and cybercrimes rise, children are especially vulnerable, often lacking the skills to manage these risks. It emphasizes the necessity of developing digital intelligence (DQ), which includes skills such as digital citizenship and media literacy, to help children navigate the digital world safely and responsibly. The global push for DQ aims to equip children with the competencies needed to thrive in a connected society [3]. The emerging trends regarding digital literacy development in Thailand are outlined in the five-year national digital economy and society action plan. The plan emphasizes the need for digital literacy to support the country's transition into the digital age. It outlines strategies such as developing human capital with appropriate digital skills across all sectors and enhancing the ability of the general population to use technology safely [4]. Therefore, enhancing the DQ of Thai youth is crucial to improving their digital safety and overall well-being [5].

To address this need, the DQ Institute introduced a learning management approach aimed at developing students' DQ. The FC learning model was chosen for its effectiveness in facilitating self-paced learning through electronic platforms, enabling students to study independently at home. Supplementary activities, such as brainstorming sessions, are then conducted in school to reinforce the learning objectives [3]. The FC model positions teachers as facilitators who guide students in achieving their learning goals. Numerous studies have demonstrated that FC learning significantly enhances student achievement, largely because this approach encourages more active student engagement compared to traditional teaching methods [6], [7].

The integration of mobile devices in education, also known as mobile learning (m-learning), involves delivering lessons through mobile phones or portable computers using wireless network technology, allowing real-time connection to servers via wireless access points [8]. The advancement of mobile technology, including improvements in efficiency, data transmission speed, and display capabilities, has enabled the development of highly functional educational applications. Mobile learning is particularly suitable for the current era, which has been profoundly impacted by the COVID-19 pandemic, as it allows students to learn from home, thereby reducing physical contact and the risk of virus transmission. Consequently, m-Learning is an appropriate complement to the FC model [9], [10], [11].

Given these considerations, the preparation of children and young people to be digitally intelligent is essential for cultivating responsible digital citizens in Thailand. This paper aims to develop strategies for enhancing the DQ of secondary school

students, addressing the current deficiency in digital intelligence skills among Thai youth. The researcher intends to develop a learning model that integrates the FC approach with a mobile application to promote DQ among secondary school students. This initiative is expected to support the development of responsible digital citizens in Thailand, both now and in the future. This study project forms part of a broader research program focused on promoting DQ among secondary school students.

2 LITERATURE REVIEW

This study aims to develop a FC learning model integrated with a mobile application to enhance DQ skills. A comprehensive literature review on mobile applications and the FC model was conducted to establish guidelines and synthesize key components. Additionally, the study analyzed existing research on DQ to inform the development of strategies for improving learners' DQ skills.

2.1 Mobile application

Touch-screen devices have replaced traditional GUIs, allowing young children to interact with digital technology naturally without the need for external devices, thereby promoting communication and collaboration [12]. Mobile applications have become integral to daily life due to their ability to simplify and enhance various activities. However, only a small percentage of current mobile educational applications are well-designed and genuinely support children's learning. Most apps merely replicate traditional learning tools, such as digital flashcards, without enhancing educational value [13]. Most educational apps available in digital stores primarily target basic academic skills. This is primarily because developers often disregard established curricula and design these apps with little to no input from developmental specialists [14]. Therefore, the development of mobile applications should align with educational curricula, learning activities, and skill development, and specialists should provide guidance during the development process.

In the realm of education, mobile applications are increasingly being utilized for mobile learning [15], [16], [17], which involves teaching and learning through mobile technology. These applications are software programs installed on mobile devices that support various learning activities, such as studying course content, watching instructional videos, taking quizzes, and interacting with peers. Mobile applications are versatile tools that can be applied across different educational levels, including teaching science at the primary education level [18], English language instruction at the secondary education level [19], and mathematics and English language at the secondary education level [20]. Additionally, augmented reality (AR) technology has been employed in mobile applications to enhance English language skills training [21], [22]. Moreover, the integration of mobile devices, such as the ScratchJr programming environment, combined with hands-on activities for teaching natural science concepts, can enhance early childhood science education and foster scientific thinking in young learners [23]. Therefore, it is evident that mobile applications can be utilized in teaching a wide range of subjects.

Currently, the development of mobile applications primarily focuses on two major platforms: iOS and Android. Developers select the platform that best aligns with their users' needs. iOS applications, which require devices with the iOS operating system, typically involve a higher cost compared to devices running the Android OS.

Conversely, Android applications offer greater flexibility in development, making them particularly suitable for diverse educational purposes. Android applications can efficiently deliver a wide range of content, including text, images, videos, practice exercises, and quizzes [24], [25], [26]. For this study, the decision was made to develop an Android application to be used in FC activities. This choice was driven by the platform's suitability for displaying lesson content, playing videos, facilitating practice exercises and quizzes, and storing student data within the application.

2.2 Flipped classroom

The FC concept was first introduced in 2000 [27] as a presentation of a learning model that integrates teaching and technology, known as Classroom Flip. It involves learning activities outside the classroom and having students engage in activities inside the classroom. This promotes self-directed learning and provides opportunities for collaborative work with peers. In the same year, the concept of learning outside the classroom was also introduced in the form of the inverted classroom [28]. This learning approach allows students to learn subject matter at home and engage in various activities in the classroom. In 2012, the concept of teaching and learning known as the FC was popularized [29]. This model typically involves students studying lesson content through videos before participating in classroom activities, thus allowing more time for active engagement and deeper understanding during class [30], [31].

The FC approach supports a blended learning environment characterized by engaging, active, collaborative, and technology-enhanced learning experiences [32]. The integration of mobile applications within the FC model further promotes collaborative learning among students [10]. Learners benefit from the flexibility and accessibility of mobile learning tools as part of the FC process [33], [34]. The FC model serves as a powerful tool for enhancing digital skills by blending online and in-class learning. The model not only improves student engagement and academic outcomes but also promotes essential digital literacy skills, making it a valuable approach in modern education. In this study, the steps of FC learning activities were synthesized from relevant studies to define the learning activities in the developed model.

2.3 Digital intelligence quotient

The widespread use of digital media has a profound impact on children and young people. It is crucial for teachers, parents, and other caregivers to engage with children in their use of digital media rather than simply prohibiting or limiting screen time. By doing so, children and young people can be encouraged to use digital media more creatively. Teaching digital literacy skills in an age-appropriate manner helps promote the responsible and innovative use of digital technology and media. When digital skills are nurtured from an early age, children and young people benefit from the ability to navigate digital media effectively, which has positive implications both for themselves and for society as a whole. This is the preparation of children to be perfect digital citizens [35].

According to the DQ Institute [3] and the work of Wannapiroon and Wattananaiya [36], the DQ comprises eight key components: 1) digital citizen identity; 2) screen time management; 3) cyberbullying management; 4) cybersecurity management; 5) privacy management; 6) critical thinking; 7) digital footprints; and

8) digital empathy. These components represent essential skills for future digital citizens. The objective of this study is to develop and enhance the skills associated with all eight aspects of the digital intelligence quotient.

3 MATERIALS AND METHODS

3.1 Research objectives

- To develop a mobile application with a FC model for improving the DQ of secondary education students.
- To develop a FC mobile application to promote students' DQ.
- To compare the DQ of students before and after learning with the mobile application with FC model.
- To assess students' satisfaction with the mobile application with the FC model.

3.2 Research samples

The research sample consisted of lower secondary school students from schools within the Nakhon Pathom Secondary Service Area in Thailand. The sample was selected using a multi-stage sampling method. In the first stage, two schools were randomly selected from a total of 29 secondary schools in the Nakhon Pathom Secondary Service Area. The next stage involved randomly selecting one grade level, ranging from Grade 7 to Grade 9, from each school. Finally, one classroom was randomly chosen from the selected grade level at each school, with 30 students per classroom. The final sample consisted of 60 students, including 37 males and 23 females.

3.3 Research instruments

1. Mobile application with FC model: A mobile application integrated with the FC model was developed to enhance the DQ of secondary education students. The learning model was created through a comprehensive study of relevant documents and research, as well as interviews with secondary school teachers to synthesize the model. The developed model was then evaluated by ten qualified experts to assess its appropriateness.
2. Flipped classroom mobile application: The mobile application designed to promote students' DQ was developed using the Google Flutter framework. This application was subsequently reviewed by five experts to assess its quality and functionality.
3. Digital intelligence quotient test: The DQ test consists of 80 multiple-choice questions, each with four options. The quality of the test was validated by calculating the Index of Item-Objective Congruence (IOC), as determined by 10 experts. The test's reliability was measured using the KR-20 formula, resulting in a reliability coefficient of 0.65.
4. Satisfaction questionnaire: A questionnaire was developed to measure students' satisfaction with the learning model and the mobile application integrated with the FC model. The questionnaire was constructed using a 5-point Likert scale and was evaluated by three qualified experts for its index of Item-Objective Congruence (IOC).

3.4 Research methodology

This study is research and development comprising two main phases: the development of learning models and mobile applications, and the experimental use of the developed learning models and mobile applications.

- **First phase:** The first phase involves the development of learning models and mobile applications, consisting of the following steps:
  1. The development of a mobile application with a FC learning model consists of the following steps.
     - 1.1 Studying relevant documents and research and interviewing secondary school teachers to synthesize the framework of learning models using a FC mobile application to promote the DQ. The results were applied to develop a learning model as follows:
       1. The components of the model should include teachers, students, and learning activities, as well as the expected learning outcome (which is the digital intelligence quotient) and earning environment consisting of learning materials and measurement and evaluation.
       2. Flipped classroom learning activities should consist of in-class and out-of-class activities. The sequence of activities comprises pre-, during, and post-activity.
       3. The mobile learning application should comprise learning materials, including text and image media, infographic media, and motion graphics; measurement and evaluation, consisting of group activities and unit exercises; and a student database system to store student learning outcomes.
       4. Learning outcomes, which are digital intelligence skills, consisted of the following 8 sub-skills [3]: 1) digital citizen identity, 2) critical thinking, 3) cybersecurity management, 4) privacy management, 5) screen time management, 6) digital footprints, 7) cyberbullying management, and 8) digital empathy.

       Flipped classroom learning management procedures research can be synthesized as Table 1 [10], [11], [32], [33], [37], [38]. From the synthesis of the FC learning process, flipped learning steps were: 1) studying new content, 2) recording learning outcomes, 3) group activities, 4) individual practices, 5) reviewing knowledge, and 6) self-assessment.
     - 1.2 The results from teacher interviews and the synthesis of the learning process were used to develop the learning model using a FC mobile application to promote the digital intelligence quotient.
     - 1.3 The developed learning model was presented to 10 qualified experts to assess the appropriateness of the model.
  2. The development of a FC mobile application to promote the digital intelligence quotient.

     The development of mobile learning applications is based on the principles of the system development life cycle (SDLC). The system development in this study was divided into five phases as follows:
     1. Requirement analysis is the study of relevant concepts and theories and data collection for developing a mobile application to promote the DQ. Documents, concepts, and data relating to the development technology of existing mobile application technologies.

2. System and software design is the application of data from the requirement analysis to design a mobile application. The design process consists of 1) system architecture design, 2) database system design, 3) graphic user interface (GUI) design, and 4) lesson content design.

Table 1. Synthesis of flipped classroom learning process

Flipped Classroom Learning Process	Lo, C. K. (2017) [37]	Halili, S. H. (2019) [10]	Lamia, M. (2019) [33]	Baharum, A. (2020) [11]	Loizou, M. (2020) [38]	Zain, F. M. (2020) [32]
Analysis learners (Pre-class, Out-of-class activities)		✓				
State objectives (Pre-class, Out-of-class activities)		✓				
Select media & materials (Pre-class, Out-of-class activities)		✓				
Goal Setting (Pre-class, Out-of-class activities)				✓		
Individual learning space, Watching instructional videos, Utilize media & materials (Pre-class, Out-of-class activities)	✓	✓	✓	✓	✓	✓
Recording learning outcomes, Completing content notes (Pre-class, Out-of-class activities)	✓				✓	✓
Taking online quizzes (Pre-class, Out-of-class activities)	✓		✓	✓	✓	
Teacher clarifies students' misunderstandings (During-class, In-class activities)				✓		
Teacher instructs extended knowledge, Teacher's lectures, Brief review and Q&A (During-class, In-class activities)	✓			✓	✓	
Group learning space, Require learner participation, Group discussion (During-class, In-class activities)	✓	✓	✓		✓	✓
Short lecture (During-class, In-class activities)	✓					
Individual practices, Practices work on groups (During-class, In-class activities)	✓		✓			
Problem solving (Post-class, Out-of-class Activities)					✓	
Review the knowledge, Conclusion and preview, Student feedback (During-class, In-class activities)	✓		✓			✓
Students-regulation: evaluation, evaluate & revise, reflection (Post-class, Out-of-class activities)		✓		✓		✓

3. Implementation and unit testing is the development of Android applications to work on phones, smartphones, and tablets. Google Flutter was used to develop a mobile application since it is a currently popular tool for easy application development.
4. System integration and testing is the system testing and improvement. The developed system was assessed for quality and performance using the black box testing technique. After testing the system quality and performance, the developed mobile application was presented to the five qualified persons to assess the quality of the mobile application.
5. System operation and maintenance is the dissemination and installation of mobile applications on the mobile devices of the sample students for learning with the developed learning model.

3. The digital intelligence quotient test.

   This study applied a DQ assessment form to assess students' DQ before and after learning with the developed learning model. It has a total of 80 questions of four multiple-choice questions. This DQ test was developed by the research project on online DQ test development for secondary school students, which is a project in the same research program as this study.
4. The development of a satisfaction questionnaire toward the developed learning model.

   The satisfaction questionnaire was constructed according to a five-point Likert scale. It was evaluated the index of item-objective congruence (IOC) by three qualified experts.

- **The second phase:** The second phase involves the experimental application of the developed learning models using a one-group pretest-posttest design, consisting of the following steps:
  1. Pretest measurement: Assess the students' DQ before the learning intervention using the online DQ test, which consists of 80 multiple-choice questions.
  2. Learning intervention: Implement the learning process based on the mobile application integrated with the FC model, where students engage in learning activities for a period of 9 weeks. The first week serves as an orientation to introduce the learning activities and guide students in installing the required software. In the subsequent weeks, students will study content related to the eight skills of DQ, focusing on one skill each week.
  3. Posttest measurement: After the learning intervention, reassess the students' DQ using the same DQ test, which consists of 80 multiple-choice questions, identical to the pretest.
  4. Satisfaction assessment: Have students evaluate their satisfaction with the learning experience provided by the developed learning model using an online survey. The survey consists of 20 key questions, covering aspects such as: 1) ease of use of the mobile applications; 2) learning activities; 3) learning materials; 4) assessment and evaluation methods; and 5) convenience in accessing student information, among other topics.
  5. Data analysis: Analyze the DQ data using a paired sample t-test to compare pretest and posttest results.
  6. Satisfaction analysis: Analyze the results of the student satisfaction assessment using the mean and standard deviation.

4 RESULTS

4.1 The development of a mobile application with flipped classroom model for improving digital intelligence quotient of secondary school students

From the synthesis of the FC learning process and consideration of the components of learning activities, it was developed into a learning model as Figure 1, and can explain the model as follows.

The components of a mobile application with a FC model for improving DQ comprise 1) teachers, 2) students, 3) a flipped classroom, 4) a digital intelligence quotient, and 5) a learning environment.

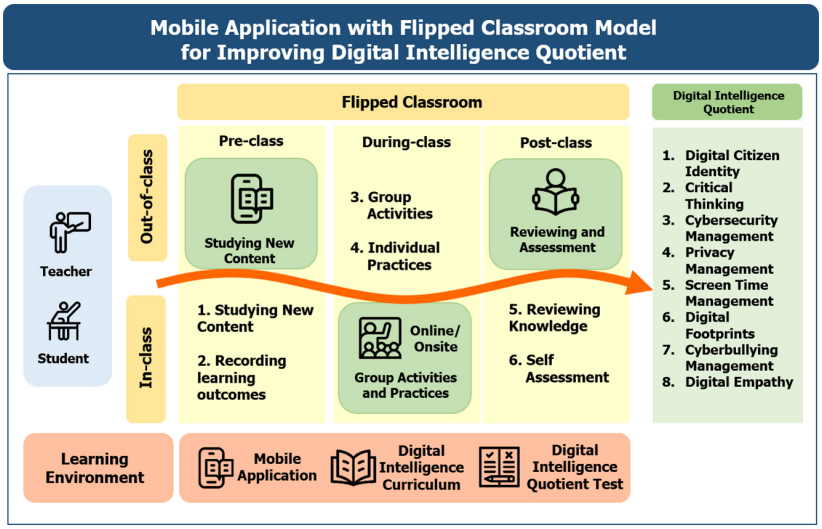


Fig. 1. Mobile application with FC model for improving digital intelligence quotient

- **Teachers:** The teacher conducts the learning according to the FC activity plan via the developed mobile application. The mobile application was used to monitor the learners' activities, i.e., the progress of learning and results of the learners' evaluation. The teacher facilitates learning and helps solve problems for learners who need help. The duties of teachers can be divided into in-class and out-of-class. For teachers' duties outside the classroom, teachers schedule to organize instructional activities each week, monitor learners' progress, answer questions about learning, and solve problems when students need help. For in-class duties, teachers organize classroom activities, divide students into groups, explain the activity process, control learner activities, answer students' questions, and help solve arising problems.
- **Students:** The duties of students, similar to teachers', are divided into out-of-class and in-class duties. Outside the classroom, students study new lessons from the video on the mobile application and record learning outcomes and questions arising from the lesson to ask the teacher when participating in class activities. For in-class duties, students conduct group activities to discuss and solve the given problems together. They are asked to record their learning outcomes and do individual exercises.
- **Flipped classroom:** The process of FC consists of three main steps: 1) pre-class activity, 2) during-class activity, and 3) post-class activity.
  1. Pre-class activities are activities that take place outside the classroom where learners study by themselves. Pre-activity consists of two sub-steps:
     - 1.1 Studying new content. Students must study new lessons before the class on the mobile application. The lesson content includes digital media, infographics, and videos.
     - 1.2 Recording learning outcomes. Students summarize and record learning outcomes on the mobile application. Questions arising from the lesson content are also noted to be discussed with friends and teachers in classroom activities.
  2. During-class activities are activities that take place in the classroom, which can be organized in a real classroom (onsite) or an online platform, depending on the situation. Students jointly do activities, and the teacher acts as an activity facilitator. There are two sub-steps as follows:
     - 2.1 Group activities are activities where students work together in groups to solve problems by discussing, exchanging opinions, and summarizing solutions. The teacher is an instructor and facilitator during activities.

2.2 The teacher assigns students to do individual exercises. Students can consult the teacher closely at any time.

3. Post-class activities are activities that students do after class. They do activities by themselves outside the class through the mobile application. There are two sub-steps as follows:
   3.1 Reviewing knowledge is a review of each lesson learned via the mobile application, by doing exercises and answering review questions.
   3.2 Students take self-assessments by doing the post-test to know the learning outcomes of each lesson.

- **Learning environment:** The learning environment that is organized as a basis for FC learning consists of 1) mobile application, 2) DQ curriculum, and 3) DQ assessment system. The details are as follows:
  1. Mobile application: The mobile application was developed based on the Android operating system, which can be installed on both smartphones and tablets. The mobile application includes lesson content in the form of digital media, infographic images, and video. It also provides functions that support learning activities and exercises for learners to review the lesson.
  2. Digital intelligence quotient curriculum: The DQ curriculum consists of eight lessons: 1) digital citizen identity, 2) critical thinking, 3) cybersecurity management, 4) privacy management, 5) screen time management, 6) digital footprints, 7) cyberbullying management, and 8) digital empathy. Each lesson consists of a learning management plan, a knowledge sheet, a worksheet, and a learning activity evaluation form. The lesson content is in the form of digital content presented on the mobile application, consisting of infographic images and instructional videos.
  3. Digital intelligence quotient assessment system: The DQ assessment system is a system developed from the research under the same research program as this study. The DQ assessment system is a web application. Students were assigned to do the DQ test before and after learning to know the development of students' digital intelligence quotient.
- **Digital intelligence quotient:** Digital intelligence quotient that needs to develop for learners using the learning model consists of the following eight sub-skills: 1) digital citizen identity, 2) critical thinking, 3) cybersecurity management, 4) privacy management, 5) screen time management, 6) digital footprints, 7) cyberbullying management, and 8) digital empathy. The DQ can be measured using the DQ assessment system, which was developed under the same research program as this study.

The developed learning model was presented to ten qualified persons to assess the appropriateness of the learning model. The results of the assessment are shown in Table 2.

Table 2. Evaluation of the appropriateness of mobile application with FC model

Items	$\bar{X}$	S.D.	Appropriateness Level
1. Principles and concepts used as the basis for the learning model development	4.90	0.32	Highest
2. The main components of the learning model	4.78	0.46	Highest
3. Flipped classroom learning activities	4.80	0.40	Highest
4. Measurement and evaluation	4.70	0.48	Highest

(Continued)

Table 2. Evaluation of the appropriateness of mobile application with FC model *(Continued)*

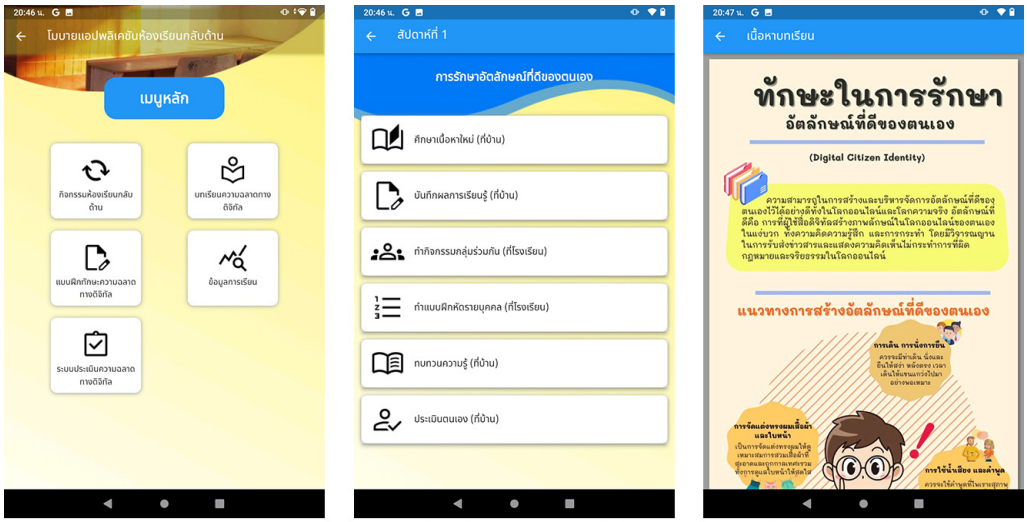
Items	$\bar{X}$	S.D.	Appropriateness Level
5. The developed learning model is appropriate for improving the DQ.	4.90	0.32	Highest
6. The process and activities of learning model appropriate for improving the DQ.	4.70	0.48	Highest
7. The developed learning model is feasible for practical implementation.	4.90	0.32	Highest
Overall	**4.80**	**0.42**	**Highest**

From Table 2, overall, the experts opined that the mobile application with a FC model for improving the DQ of secondary education students was appropriate at the highest level with an average of 4.80. As a result, the expert evaluation was rated at the highest level across three aspects: 1) the foundational principles for the development of the learning model, 2) the appropriateness of the learning model for enhancing DQ, and 3) the feasibility of implementing the developed learning model in practice.

4.2 Results of the development of flipped classroom mobile applications to promote students' digital intelligence quotient

The FC mobile application to promote students' DQ was developed in Android using Google Flutter, so that the application can be run on smartphones and tablets. The application consists of a student module and teacher module follows:

- Student module: The student module provides functions that support flipped learning activities as shown in Figure 2, such as the main menu screen as shown in Figure 2a, the FC activities for learners to do FC activities as shown in Figure 2b, and the lesson content as shown in Figure 2c. The application also includes a DQ Assessment System menu. It's a menu for connecting to the DQ Assessment System for learners to test their DQ before and after learning.

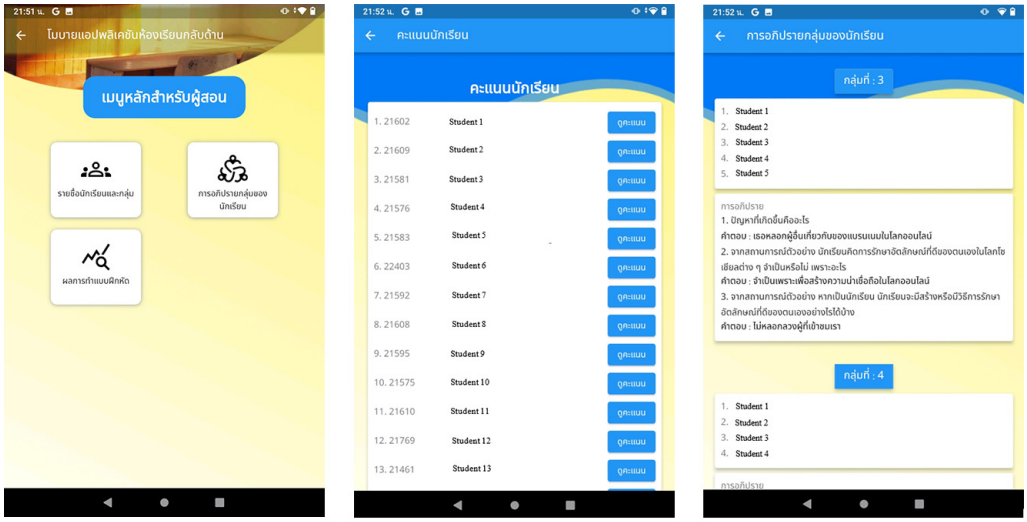


(a) Student's Main Menu (b) Flipped Classroom Activities (c) Learning Content

Fig. 2. Flipped classroom mobile application for student module

- Teacher module: The teacher module provides functions that support teachers in viewing the data of students and learning activities, as shown in Figure 3, such as the main menu screen for teachers as shown in Figure 3a, the students list as shown in Figure 3b, and the students group activities in the classroom as shown in Figure 3c.

  The result of the content quality assessment of the FC mobile application to promote students' DQ was overall at a very good level. Overall, the technical quality assessment also showed a very good level. To assess the effectiveness, the FC mobile application to promote the DQ was tested with a group of learners who were not a sample. The effectiveness of the developed mobile application (E1/E2) was equal to 82.33/81.17, which was in line with the set criteria of 80/80.



(a) Teacher's Main Menu (b) Students List (c) Group Activities in Class

Fig. 3. Flipped classroom mobile application for teacher module

4.3 The result of comparison of students' DQ before and after learning with the developed learning model

Table 3. Results of comparison of students' DQ before and after learning

Test	n	Full Score	$\bar{x}$	S.D.	t-Test	p-Value
Pre-test	60	80	26.61	4.86	57.65	0.00*
Post-test	60	80	62.10	5.04		

Note: *p < 0.05.

According to Table 3, the results indicate a significant improvement in students' DQ after learning with the developed FC mobile application model. The students' average post-test score ($\bar{x}$ = 62.10, S.D. = 5.04) was significantly higher than their pre-test score ($\bar{x}$ = 26.61, S.D. = 4.86), with a t-test result showing statistical significance at the 0.05 level (t = 57.65, p = 0.00). The research results show that the developed learning model can enhance the DQ of the students. This finding aligns with the established hypothesis.

When considering the students' DQ in each area, the comparison of students' DQ skills before and after the course is shown in Table 4.

Table 4. Results of comparison of students' DQ before and after learning in each skill

DQ Sub-Skills	Pre-Test		Post-Test		t-Test	p-Value
	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
1. Digital citizen identity	3.62	1.49	7.45	1.06	18.24	0.00
2. Critical thinking	3.23	1.29	7.85	0.99	23.20	0.00
3. Cybersecurity management	3.25	1.02	7.92	0.98	27.58	0.00
4. Privacy management	3.53	1.08	7.78	0.94	27.71	0.00
5. Screen time management	3.42	1.20	8.13	1.13	24.22	0.00
6. Digital footprints	3.35	1.22	7.82	1.11	21.92	0.00
7. Cyberbullying management	3.05	1.08	7.73	1.02	26.70	0.00
8. Digital empathy	3.17	1.28	7.42	1.03	23.16	0.00

Note: *p < 0.05.

Table 4 indicates that all sub-skills of the DQ showed statistically significant improvement in post-test scores compared to pre-test scores at the 0.05 significance level. When considering in details eight skills, learners were found to have the highest skill in screen time management ($\bar{x}$ = 8.13, S.D. = 1.13), followed by skill in cybersecurity management ($\bar{x}$ = 7.92, S.D. = 0.98), and critical thinking skills ($\bar{x}$ = 7.85, S.D. = 0.99), respectively. The sub-skill with the lowest average score was digital empathy ($\bar{x}$ = 7.42, S.D. = 1.03). The average post-test scores of each aspect of the DQ skills can be represented in Figure 4.

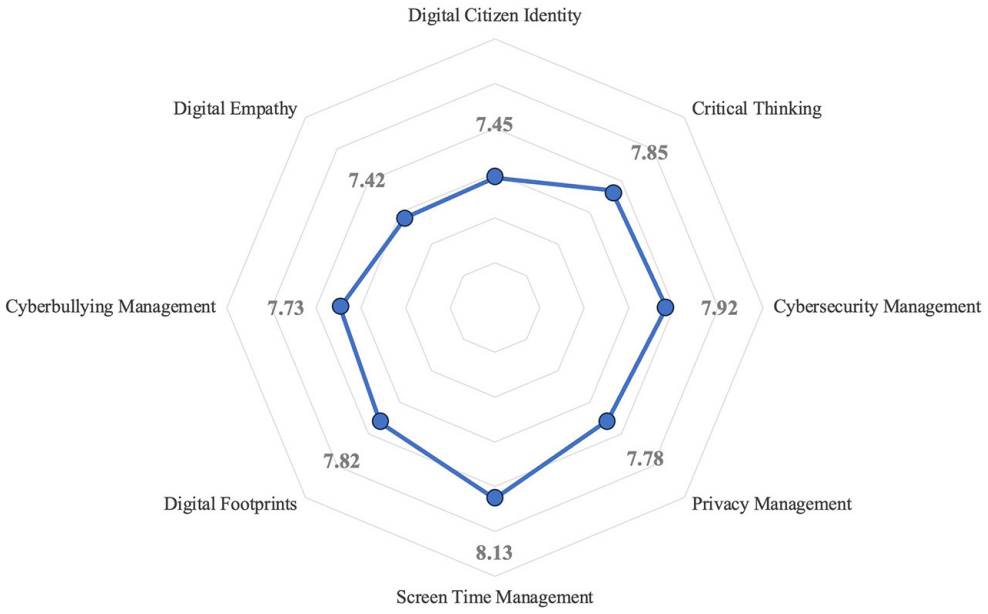


Fig. 4. Result of comparison of students' DQ in each skill

4.4 The results of students' satisfaction with the mobile application with flipped classroom model for improving digital intelligence quotient of secondary education students

According to the satisfaction assessment, it was found that students were overall satisfied with the mobile application with the FC model at the highest level ($\bar{x}$ = 4.66, S.D. = 0.53). The top three evaluation criteria were: 1) The application is easy to use ($\bar{x}$ = 4.83, S.D. = 0.38), 2) Students receive accurate and prompt score feedback ($\bar{x}$ = 4.80, S.D. = 0.40), and 3) The assessment and evaluation methods are appropriate ($\bar{x}$ = 4.78, S.D. = 0.42).

5 DISCUSSION

Regarding the development of the mobile application integrated with the FC model for improving the DQ of secondary education students, the overall assessment results were rated at the highest level. This success may be attributed to the careful design of the learning model, which incorporated essential components of FC management that effectively promote DQ. These components align well with the learning management process and are suitably adapted for use within the application. Given that FC management emphasizes pre-class learning, the use of application technology is particularly appropriate, facilitating students' study at home as well as their participation in in-class group activities via the application.

The learning model defines the roles of teachers, students, and the steps involved in FC activities according to the designed learning management plan. It also includes appropriate learning assessment methods, with the development of a mobile application aligned with the FC learning model. The evaluation highlighted that the learning model was based on sound principles and concepts, effectively enhanced the DQ, and was feasible for practical implementation. The concept of FC learning applied in this study aligns with the research conducted by Jantakoon and Piriyasurawong [39]. The FC approach, supported by the mobile application, proved to be an effective pedagogical method. It facilitated self-directed learning, encouraged more interactive and collaborative in-class activities, and contributed to better retention and understanding of digital intelligence concepts.

In terms of content and technical aspects, the quality of the developed FC mobile application was assessed at a very good level. Particularly in terms of the appropriateness of the lesson content for experimental implementation, the function of application, and the efficiency of application. This positive assessment may be due to the application being developed according to the Software Development Life Cycle (SDLC) process [40], which ensures rigorous control over application development and testing to meet users' needs. Additionally, the mobile application was developed for the Android platform, as most students use Android mobile phones, ensuring that they can utilize the application on their own devices. It includes two main modules: the student module, which supports flipped learning activities and provides access to lesson content and a DQ Assessment System, and the teacher module, which allows teachers to view student data, manage learning activities, and monitor classroom group activities. These modules facilitate the FC approach through a user-friendly interface. Subsequently, students attended classes via FC activities and completed exercises to reinforce their DQ. The use of mobile applications in learning management in this study is consistent with the study by Baharum et al. [11], which developed a mobile application using the FC model and received positive acceptance from students.

The comparison of the DQ of secondary education students before and after learning with the developed learning model demonstrated a significant improvement in students' DQ post-intervention. This improvement may be attributed to the effectiveness of the FC learning process. Students studied the lesson content independently at home and participated in in-class group activities through the mobile application. Moreover, students had the opportunity to review their knowledge at any time using the mobile application. The application also included exercises designed to practice all eight DQ skills, tailored to the learners' needs. The improvement was observed across all eight components of DQ, including digital citizenship identity, critical thinking, cybersecurity management, privacy management, screen time management, digital footprints, cyberbullying management, and digital empathy. When considering the sub-skill that showed the most improvement among students, screen time management was the highest. This may be attributed to the lesson content being closely related to students' daily lives and personal experiences. Students demonstrated a strong understanding of the material, such as content related to the negative impacts of excessive screen time and methods for managing screen time effectively, especially in children. This finding is consistent with Aslan's research [41], which studied the FC learning model to develop digital literacy skills and online teaching competencies, and the result showed an increase in learners' skills. Similarly, the results align with the research by Lamia et al. [33], which found that developing a mobile learning system has positive effects on students' knowledge, skills, and motivation in the flipped classroom.

Regarding satisfaction with the learning model, students were overall satisfied at the highest level. This highest level of satisfaction may be attributed to the flexibility offered by the mobile application, which allowed students to access lessons anytime and anywhere. The use of personal devices enabled students to engage with the material at their own pace, which likely enhanced their learning experience. The innovative format of the learning activities, which differed from traditional teaching methods, also helped to capture and maintain students' interest. Additionally, the opportunity to practice using information technology and mobile devices as learning tools further contributed to the positive response. Based on the satisfaction evaluation, students expressed the highest satisfaction with three key aspects. The first was the ease of use of the application, as it featured user-friendly navigation menus that allowed for quick access to lesson content and activities. The second aspect was the immediate feedback on scores, which satisfied students by providing instant results on their exercises and quizzes. The third aspect was the assessment and evaluation methods, as students found it convenient to complete tests via the application on their mobile devices. These findings are consistent with the research conducted by Liu et al. [42], which demonstrated high levels of student satisfaction with mobile learning management. Similarly, the results align with the research by Talan and Gulsecen [6], showing that students were generally satisfied with the FC as well.

These findings suggest that integrating mobile learning with FC models can be a powerful tool in enhancing essential digital skills among secondary education students, preparing them for responsible digital citizenship in the modern world.

6 CONCLUSION

This study developed and implemented a mobile application integrated with a FC model to enhance the DQ of secondary education students. The findings indicate that the FC model, supported by mobile learning, significantly improves students'

DQ across all measured skills. The mobile application allowed students to engage with the material in a flexible and interactive manner, fostering self-directed learning and deeper understanding. The results also demonstrate high levels of student satisfaction with the learning model, suggesting its effectiveness and potential for broader application in educational settings. By leveraging mobile technology, the FC model provides a viable approach to modern education, particularly in developing essential digital skills needed for responsible digital citizenship. This study contributes valuable insights into the integration of digital learning tools with innovative pedagogical models, paving the way for more effective and accessible education strategies that prepare students for the challenges of the digital age. The developed model and application to enhance the DQ of secondary school students in Thailand represent an innovative approach to advancing digital education for youth.

However, the study does have several limitations. The results show a clear improvement in DQ scores, but variables such as the novelty of the mobile app and FC approach may have temporarily increased student engagement. However, the study did not assess long-term retention of DQ skills, raising concerns about the sustainability of these gains. Future research should include longitudinal assessments to determine how well students retain and apply these skills over time.

The absence of an iOS version limits the mobile application's accessibility, affecting its generalizability to a broader student population. This limitation is significant in contexts with diverse device usage, potentially introducing bias by assuming uniform access to technology. In future research, applications should be developed to be compatible with a wider range of operating systems, such as iOS.

The study did not fully explore key variables like students' prior digital literacy, socioeconomic background, and home technology access, which likely influenced their ability to benefit from the learning model. Future research should examine how these factors interact with the FC and mobile learning to provide deeper insights into which students gain the most from these interventions.

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