Effects of Collaborative Inquiry-Based Online Approach in Thai University Students' Computing Program

Krittawaya Thongkoo[1,*], Kannika Daungcharone[1,*], and Patcharin Panjaburee[2]

[1]College of Arts, Media and Technology, Chiang Mai University, Thailand
[2]Faculty of Education, Khon Kaen University, Thailand
Email: krittawaya.t@cmu.ac.th (K.T.); kannika.d@cmu.ac.th (K.D.); patchapan@kku.ac.th (P.P.)
[*]Corresponding author
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***Abstract*—In response to the evolving demands of the digital era, the significance of programming skills has led to a reevaluation of traditional classroom instruction. This study introduced a collaborative inquiry-based online system to enhance individual and peer-supported coding practice. Through a quasi-experimental design, 346 Thai undergraduates were divided into a control group, which continued with conventional classroom teaching, and an experimental group that utilized the collaborative inquiry-based online approach. The research assessed conceptual learning performance via a pre- and post-test consisting of 15 questions. In addition, perceptions of the learning environment and motivation were assessed through 19-item and pre-post questionnaires with 20 items, respectively. The results indicated that the experimental group outperformed the control group in understanding programming, problem-solving abilities, and coding proficiency. Furthermore, the students in the experimental group demonstrated higher engagement and motivation, alongside improved teamwork and communication skills, which are essential in the modern online learning environment. This study suggests collaborative inquiry-based online learning can effectively complement or replace traditional instruction, offering valuable insights for educators, instructional designers, and policymakers. It advocates for a shift towards a more student-centered, interactive, and engaging learning experience in computer science education.**

***Keywords*—technology-enhanced learning, online learning, higher education, computer science education**

I. Introduction

In the current age of digital transformation, programming skills have become increasingly vital for students pursuing higher education, particularly those in Science, Technology, Engineering, and Mathematics (STEM) fields [1, 2]. Despite the escalating demand for these skills, learning to program remains daunting for many students, often characterized by high attrition rates and low self-efficacy. Traditional programming pedagogies, predominantly lecture-based, have been noted for their limitations in fostering more profound understanding and practical skills [3]. The challenge in effectively teaching programming becomes even more pronounced in the context of online learning, where students may feel isolated, less engaged, and need help grasping abstract concepts [4].

The emphasis on programming skills in higher education is essential as higher education prepares people for the labor market, especially the IT market. Therefore, getting jobs after graduation is the primary goal of many educational institutions [5]. To be employed, graduates must possess specific qualifications required by particular workplaces, such as learning performance, experience, or specialized abilities. These factors indicate the quality of education.

In recent years, research in higher education has been increasing to enhance graduates' acceptance by society and entrepreneurs. Integrating technology into pedagogy to improve student learning and academic achievement is one component of increasing educational quality [6, 7]. Technology and the internet have transformed the traditional classroom into a more flexible and dynamic learning environment [8, 9]. Online learning pedagogy has become popular in higher education institutions, allowing students to access learning materials and resources anytime and anywhere. Particularly during the COVID-19 pandemic, every country worldwide needs to find measures to cope with the crisis, ranging from social distancing measures to efforts on the country's shutdown, economy, and educational institutions [10, 11].

Consequently, each educational institution has urgently switched to online learning models. Most learning processes are affected, and many students still face problems accessing technology when urgently entering the academic world [12]. Moreover, educational institutions need to prepare to cope with urgent situations in the future. Several researchers found that critical changes in learning models caused various problems, such as a lack of technical skills and instruments and obstacles in accessibility [13, 14]. Some students reported needing more learning motivation and concentration [15]. Such challenges may not benefit students' online learning [16].

There are some challenges pointed out by the previous studies, including fostering student engagement [4], collaborative learning [17], and creating knowledge [18]. Therefore, the current study explored the effects of a Collaborative Inquiry-Based Online (CIBO) approach on university students' programming learning. Constructivist learning theories inspire the CIBO approach and emphasize active, student-centered learning through shared problem-solving and inquiry. This study aims to investigate whether this approach can enhance students' programming learning performance, including learning achievement, perception, and motivation toward the online learning environment, and to understand how students satisfy and engage with online learning.

Following this deliberation, a programming experiment was conducted with university students using HTML and PHP to investigate the following research questions:

1) Do students using the CIBO approach achieve different learning outcomes than those using conventional online learning?
2) Do students using the CIBO approach have different

perceptions of their learning experience than those using conventional online learning?

3) Do students using the CIBO approach exhibit different learning motivations than those using conventional online learning?

II. Literature Review

Following the global COVID-19 pandemic, society has encountered a massive digital transformation in a new era. Therefore, education is not resistant to these changes. Several digital technologies, including mobile devices, smartboards, MOOCs, tablets, laptops, simulations, dynamic visualizations, Augmented Reality (AR), Virtual Reality (VR), Internet of Things (IoT), and virtual laboratories [19, 20], have been introduced into the educational sector to improve teaching and learning, emphasizing online learning-based instruction. Furthermore, using the technology mentioned above plays a significant role in education. The study of student perception and learning motivation when using those technologies should still be emphasized by teachers when changing classroom learning formats in preparation for this potential change.

A. Online Learning Pedagogy

Numerous variables of learning preferences, prior experience with technology, and motivation impact the online learning pedagogy of students [21, 22]. Students consistently utilize the interactive features of the online learning platform by engaging in group activities, interacting with peers, and exchanging ideas [23] and by using virtual communication spaces such as social media and discussion forums [24, 25]. These virtual communication spaces facilitate the development of student relationships in the absence of face-to-face communication. Although they may participate less actively in group discussions and activities, they still achieve their learning objectives. Thus, a blended strategy incorporating active participation and passive consumption elements could be considered. This strategy allows students to actively engage in certain aspects of the online learning environment while enrolling in other courses [26–29]. Students who utilize adaptive learning strategies typically modify their learning strategies in response to their performance and feedback [30, 31]. They may modify their strategy based on the unique requirements of a course or the obstacles they encounter.

Educators must recognize the diversity of student approaches to online learning pedagogy and offer a variety of resources, including textbooks, MOOCs, interactive educational materials, interactive applications, and other digital tools [32], as well as opportunities to cater to various learning styles and preferences.

B. Students' Perceptions toward Online Learning Pedagogy

Students' perception of online learning pedagogy can vary depending on personal learning preferences, prior experiences, technological competence, and the quality of online courses encountered [33, 34]. Many students appreciate the flexibility that online learning provides, enabling them to juggle their education with other commitments like family, work, and extracurricular activities. They might view online education as a more practical alternative to traditional face-to-face education. Nevertheless, some students may view online learning as isolating and lacking social interaction and collaboration opportunities. They may miss common interactions with peers and teachers in conventional classrooms [35, 36].

Additionally, students may recognize the importance of self-discipline and motivation in online learning as they are frequently responsible for managing their schedules and due dates [37]. For some, this may be empowering, while for others, it may be stressful or aggravating. Some students may view online education as inferior to traditional education [38]. In contrast, students who can adapt to online learning may perceive it as a more personalized experience that enables them to access learning materials at their own pace, focus on areas of interest, and increase their access to education [39]. However, students with geographical, financial, or other obstacles are not eligible.

Educators should be aware of these varying perceptions when designing and implementing online courses to create an inclusive and engaging learning environment that addresses potential obstacles and meets the diverse needs of students. This concern is important because the goal is to create an inclusive and engaging learning environment.

C. Learning Motivations through Technology-Enhanced Learning

Several motivational factors influence students' engagement and success in technology-enhanced learning environments [40, 41]. When educators have a better understanding of these factors, they can more effectively design online courses that are also more engaging. Numerous studies [42–44] have demonstrated that many students are motivated when they perceive the learning material as relevant to their goals, interests, or career objectives. Integrating real-world examples, case studies, and practical applications can enhance the significance and value of the learning experience [4, 45–47] and similarly would apply to technology-enhanced learning [48]. Therefore, providing students with clear learning objectives, scaffolding difficult tasks, and providing constructive feedback can help them develop confidence and a sense of accomplishment.

Similarly face-to-face classes, teachers must allow students to make decisions and take charge of their learning experience to foster autonomy and intrinsic motivation when participating in technology-enhanced learning. This experience may involve allowing students to choose a project topic, collaborating with peers, or engaging in self-assessment to motivate them to engage more deeply with the learning material [49, 50]. Furthermore, instructional materials incorporating game-like elements such as points, badges, and rankings can appeal to students' innate desire for competition and achievement and motivate them to engage with the learning material with the support of instructors and peers. These can aid students in overcoming obstacles and maintaining motivation throughout their educational experience with technology-enhanced learning. By incorporating these types of motivational factors into the design and implementation of a technology-enhanced learning environment, teachers are able to increase student engagement, overall success, and satisfaction with their

educational experiences [51–54].

III. Research Methodology

A. Participants

Participants were selected from five universities in five Thai regions that responded to a request for data collection under a research project funded by the National Research Council of Thailand (NRCT). Within each university, participants were divided into two groups. The researcher used the systematic sampling technique by grouping the first group into an experimental group and the second group into a control group. All participants studied computer education-related courses. None of them had prior HTML/PHP programming experience. The sample consisted of 346 students divided into the Experimental Group (EG) and the Control Group (CG). In the EG, 170 students learned through the CIBO approach, whereas 176 students in the CG learned through an online support system combined with traditional learning.

B. The Collaborative Inquiry-Based Online (CIBO) Learning Environment

This study proposed an enhanced collaborative and inquiry-based learning approach, which leverages collaborative learning among students to facilitate knowledge sharing and group work. This approach integrates inquiry-based learning principles, encouraging students to find solutions and develop problem-solving skills independently. The aim is to construct an online learning support system for an undergraduate computer programming course. Fig. 1 depicts the conceptual development model for the proposed system. An online collaborative inquiry-based approach was devised to support learning activities that motivated students to construct basic programming knowledge systematically and logically, emphasizing HTML and PHP fundamentals. To encourage learners' programming learning and enjoyment in writing complex programs, four topics were covered: 'PHP structure' taught students about the basic structure of PHP scripts and how they can be embedded in HTML files; 'HTML-PHP forms' focused on creating HTML forms and processing them with PHP; and 'Control Statement' (such as if, if...else) and 'Repetition Structure' (such as for, while...do, do...while). This feature enabled them to create more dynamic and interactive web applications by controlling the program's flow based on specific conditions and 'creating PHP functions' for particular applications. Learners were taught to define and call functions, use parameters and return values, and understand the variable scope. They also learned about PHP built-in functions and how to use them effectively. This study used HTML5, JavaScript, PHP, Google Cloud Datastore, the Laravel framework as a website framework, and the Firebase framework for real-time work to build the system.

There are several reasons why the online system was chosen for this study. Firstly, online courses offer enhanced opportunities for student collaboration [55, 56]. Secondly, as long as an internet connection is available, anyone can access the online courses from anywhere in the world and on various devices, including a desktop computer, laptop, smartphone, or tablet [57]. When students complete individual assignments in online courses, teachers can immediately review them and provide feedback. Students can learn more quickly and modify future assignments if they receive feedback more quickly.

The approach employed is collaborative and inquiry-based, and it involved utilizing a course management system, an inquiry-based learning system, a collaborative coding editor, and a database, as illustrated in Fig. 1. The course management system facilitated the provision of instructional materials on basic HTML and PHP programming by educators to learners as well as offering direction based on the learners' coding program. The inquiry-based learning system provided a platform for students to engage in self-directed study of the fundamental principles of HTML and PHP programming. This system allowed students to receive relevant questions and independently explore programming language concepts through coding. Furthermore, integrating a collaborative coding editor featuring live messaging and annotation tools allowed students to engage in coding, communicate effectively, and discuss coding with their peers. In addition to the coding logs, the database also documented the students' learning activities.

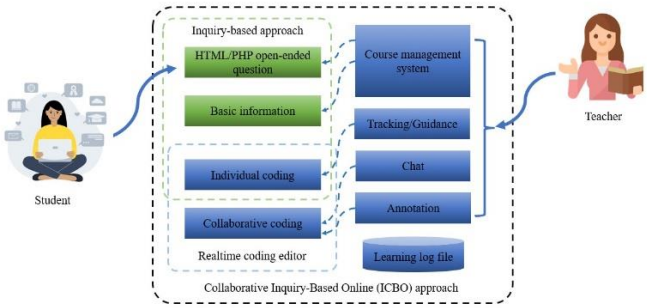

Fig. 1. The proposed learning environment.

C. Measuring Tools

The study employed several research instruments: a pre-test and post-test, a questionnaire on demographic information, a questionnaire on perception, and a questionnaire on learning motivation. A group of three instructors, expertizing in teaching programming-related courses, designed pre-and post-tests to assess the level of knowledge acquisition among students before and after attending the class.

Every examination comprised 15 questions in the multiple-choice format, where each accurate answer was assigned one point. Consequently, the overall score for each test was fifteen. The internal consistency of the pre-and post-test Kuder-Richardson Formula 20 value was deemed acceptable, as indicated by a value of 0.75. The questionnaire administered to participants comprised demographic information such as gender, academic level, field of study, institution of learning, and proficiency in Information and Communication Technology (ICT).

The questionnaire utilized in this study was derived from Liaw's work [58] and was designed to assess perception. It comprised 19 items that were categorized into five dimensions: User Interface Design (UID), Perceived Usefulness (PU), Perceived ease of Use (POU), Attitudes (AT), and Intention to Use (IU). Each dimension consisted of three, six, five, three, and two items. The survey instrument

employed a Likert scale consisting of a statement and five response options, each rated on a five-point scale. The available options enabled participants to indicate their degree of concurrence or discordance, with 'Strongly Disagree' representing one end of the spectrum, followed by 'Disagree,' 'Neither Agree nor Disagree,' 'Agree,' and 'Strongly Agree' at the other end. The internal consistency and reliability of the UID, PU, POU, AT, and IU were deemed satisfactory, as evidenced by their respective Cronbach's alpha values of 0.895, 0.928, 0.918, 0.854, and 0.866. Moreover, the present survey exhibited high reliability, as evidenced by a Cronbach's alpha coefficient of 0.974. No items were excluded from the scale due to the already limited number.

Panjaburee and Srisawasdi [59] translated Glynn's [60] questionnaire on science motivation into Thai. The questionnaire comprised 20 items that were categorized into four dimensions, namely Intrinsic Motivation (IM), Self-Determination Motivation (SDM), Self-Efficiency Motivation (SEM), and Career Motivation (CM), each of which comprised five items. The survey employed a five-point Likert scale, wherein the options ranged from 'Strongly Disagree' at one end to 'Strongly Agree' at the other, with intermediate options of 'Disagree,' 'Neither Agree nor Disagree,' and 'Agree.' The internal consistency reliability of IM, SDM, SEM, and CM was strong, as evidenced by Cronbach's alpha values of 0.724, 0.702, 0.797, and 0.771, respectively. Moreover, the present survey exhibited high reliability, as evidenced by Cronbach's alpha coefficient of 0.920.

D. Experimental Procedure

This study employed a quasi-experimental research design to collect data from two groups of students. The total duration of the experiment for each group was 210 minutes. As depicted in Fig. 2, before the learning activity for four chapters ('PHP structure,' 'HTML-PHP forms,' 'Control Statement,' and 'Repetition Structure'), both groups of students were requested to complete a demographic information questionnaire, a pre-test aimed at evaluating their pre-existing knowledge of basic HTML and PHP programming, and a pre-motivation questionnaire designed to gauge their level of motivation towards programming. The duration of this activity was 30 minutes. Subsequently, the instructor initiated the learning activity in each chapter, which lasted for 20 minutes. The experimental group acquired knowledge through a collaborative inquiry-based online approach encompassing inquiry-based learning procedures (open HTML/PHP questions, fundamental HTML/PHP information, personal coding exploration), real-time individual and group code editor areas, annotation tools, and live chat. In addition to traditional learning, the control group was provided solely with an online learning support system. Subsequently, the instructor, who was expected to lead both groups, provided an overview of the fundamental principles of HTML and PHP programming, followed by a 120-minute session of code discussion and individual code revisions.

After completing all four chapters of learning activities, the students underwent a post-test evaluation, followed by completing the motivation and perception questionnaires, which took approximately 40 minutes to accomplish after their engagement in the learning.

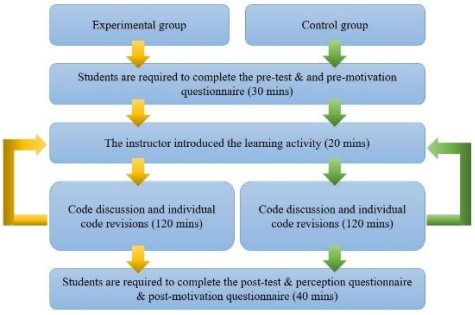

Fig. 2. Experimental procedure.

IV. Results

A. Learning Achievement

The impact of the systems on the students' educational achievement was determined by utilizing their pre-and post-test scores. As shown in Fig. 3, the study findings indicated that there was no significant difference observed between the pre-test scores of the experimental group (N = 170, Mean = 6.74, SD = 2.08) and the control group (N = 176, Mean = 6.64, SD = 2.30) (t = 0.419, p = 0.675). The results suggest that the pre-test scores of both groups were comparable. Before the commencement of the experiment, it was observed that both groups exhibited similar levels of knowledge or skills, as evidenced by the following outcomes.

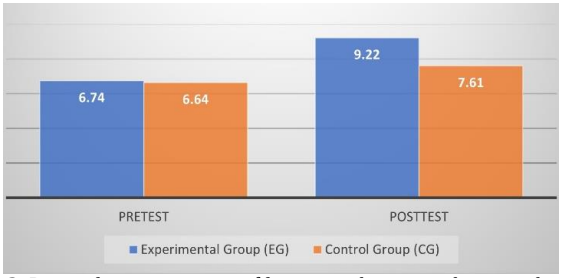

Fig. 3. Pre- and post-test scores of learning achievement between the two groups.

A one-way ANCOVA test was performed to investigate the impact of two different learning approaches on learning achievement while controlling for prior knowledge. The pre-test scores of learning achievement were utilized as a covariate, the learning approach was considered as the independent variable, and the post-test scores of learning achievement were treated as the dependent variable. Before conducting the one-way ANCOVA test, multiple hypotheses were evaluated. The normality of the standardized residuals for the interventions was established through the Shapiro-Wilk test ($p > 0.05$). Additionally, the homogeneity of variances was confirmed. Thus, the one-way analysis of covariance (ANCOVA) could be employed to compare the post-test scores of two groups while controlling for the pre-test score as a covariate.

As shown in Table 1, there was a significant difference in the post-test scores between the two groups ($F_{(1,343)}$ = 5.737, p = 0.002, η^2 = 0.094). The implication is that using the CIBO approach may lead to superior academic outcomes for students compared to combining conventional learning and online support. The efficacy of CIBO implementation may be subject to human factors. Thus, the subsequent section will illustrate the influence of the devised system on students' academic achievement.

Table 1. ANCOVA analysis of students' post-test scores of learning achievement

Group	N	Unadjusted		Adjusted		$F_{(1,343)}$	η^2
		M	SD	M	SE		
EG	170	9.223	2.874	9.194	0.186	5.737*	0.094
CG	176	7.613	2.581	7.642	0.182		

*$p < 0.05$

B. Learner Perceptions

The Shapiro-Wilk test was employed to assess the distributional characteristics of the data before conducting inferential statistical analyses. The obtained data sets exhibited normal distribution ($p > 0.05$). Thus, the dataset was suitable for conducting parametric tests. The T-test was deemed suitable for comparing the mean disparities between two distinct groups (i.e., experimental and control groups) concerning each perception dimension. The results indicated that the Experimental Group (EG) students had significantly higher scores for Attitude ($t = 2.962$, $p = 0.003$) and Intention to Use ($t = 4.712$, $p < 0.001$) compared to the Control Group (CG) students, as shown in Table 2 and Fig. 4. According to student perceptions, the utilization of a Collaborative Inquiry-Based Online approach (CIBO) was perceived as a more effective means of enhancing their understanding and fostering their motivation to learn to program, as opposed to an online learning support system integrated with traditional learning methods.

Table 2. The independent t-test results of students' perceptions

Dimension	EG (n = 170)	CG (n = 176)	t
	M ± SD	M ± SD	
UID	3.953 ± 0.719	3.849 ± 0.702	1.367
PU	3.924 ± 0.688	3.811 ± 0.641	1.578
POU	3.849 ± 0.655	3.735 ± 0.658	1.618
AT	4.008 ± 0.603	3.807 ± 0.658	2.962*
IU	4.162 ± 0.715	3.795 ± 0.731	4.712*

*$p < 0.05$

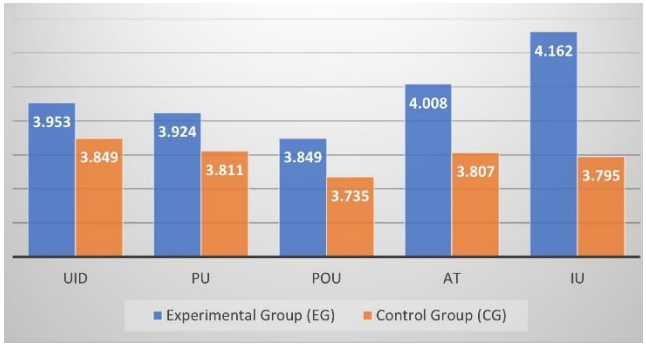

Fig. 4. Learning perceptions of the two groups.

Furthermore, the correlation between the five perceptual dimensions was validated. The Pearson correlation coefficient was computed for each pair of dimensions. Table 3 depicts the interrelationship among the five dimensions. The findings indicated that the students enrolled in EG exhibited a higher inclination towards sustained utilization of the collaborative inquiry-based online system, owing to their perception of the system's learning activities and services as conducive to enhancing their comprehension and academic progress.

Table 3. The Pearson's correlation coefficient of students' perceptions among the five dimensions of the questionnaire

Dimension	UID	PU	POU	AT	IU
UID	1				
PU	0.936*	1			
POU	0.883*	0.897*	1		
AT	0.897*	0.909*	0.925*	1	
IU	0.814*	0.818*	0.814*	0.838*	1

*$p < 0.01$

C. Students' Motivations toward the Learning Support System

The study employed a one-way MANOVA to examine the learning motivation of two distinct groups of students. After online collaborative inquiry-based instruction, the aim was to understand the dissimilarities in motivation towards HTML and PHP programming languages. The study found a significant difference in motivation levels between the HTML and PHP programming languages, as indicated by the statistical analysis: $F_{(1,341)} = 10.235$, $p < 0.0005$; Wilk's = 0.893, partial $\eta^2 = 0.107$. Table 4 and Fig. 5 present the average scores for four motivation dimensions.

Table 4. The descriptive data of the four dimensions of HTML/PHP programming language motivation

Dimension	Group	N	Mean	SD	$F_{(1,341)}$
IM	EG	170	4.065	0.043	10.589*
	CG	176	3.715	0.043	
SDM	EG	170	4.064	0.046	7.777*
	CG	176	3.764	0.045	
SEM	EG	170	3.939	0.044	4.253*
	CG	176	3.717	0.043	
CM	EG	170	3.968	0.044	8.143*
	CG	176	3.661	0.043	

*$p < 0.05$

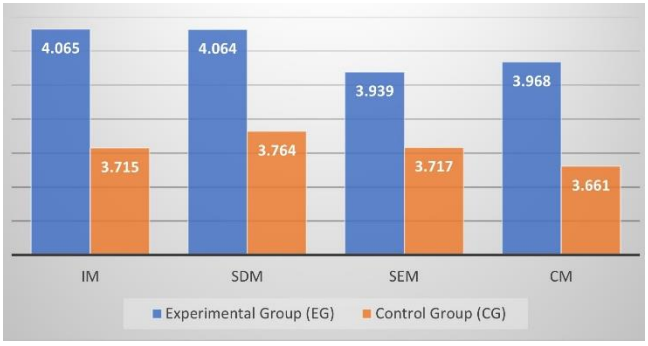

Fig. 5. Learning motivations of the two groups.

V. Discussion

This study highlights the significance of comprehending students' perceptions and motivation within online learning pedagogy. By addressing students' needs and preferences, educators can develop more effective instructional strategies and support mechanisms to improve learning outcomes in technology-enhanced learning environments [48, 61–63]. The present research evaluated the academic achievement of novice learners who were registered in computer-related courses at five universities in Thailand. The study employed a Collaborative Inquiry-Based Online (CIBO) system as a technological learning tool. The findings of this research suggest that the employment of a collaborative inquiry-based online system, which leveraged the principle of collaboration

to address the limitations of inquiry-based learning activities, proved to be more efficacious in facilitating students' learning outcomes and enhancing their perceptions of fundamental HTML/PHP programming compared to the online learning support system combined with traditional learning. Three aspects of learning accomplishment, perception, and motivation were highlighted as the key findings of our study. Firstly, students who used the CIBO approach improved their learning outcomes on the topic more than those who used an online learning support system combined with traditional learning. Secondly, the CIBO and the traditional approaches, including online learning support, contributed to student achievement. These results support the notion that technological instruments have a noteworthy impact on collaborative inquiry-based learning approaches. Zhu *et al.* [64] proposed that a computer-supported collaborative inquiry-learning environment could enhance students' collaborative, problem-solving, and critical thinking abilities. Before advancing to the subsequent phase, individuals within task-oriented groups commonly verified that all group members possessed a mutual comprehension of the correlation between the variables. The findings suggest a higher likelihood of process regulation without attaining a shared understanding among the students in groups where task completion was unsuccessful. Moreover, Chen *et al.* [65] developed a web-based inquiry learning mode with collaborative digital reading annotation system support (WILMCDRASS) to provide an innovative teaching mode that effectively improves the information evaluation skills of students in primary schools. Learners in the experimental group who utilized the proposed system for an information literacy course demonstrated significantly greater learning effectiveness and technology acceptance than learners in the control group. According to the research findings, students with low prior knowledge and field-independent cognitive style benefited the most from the use of WILMCDRASS. Chan and Pow [66] also revealed that utilizing a social annotation tool aided in the initial phases of CIL by enabling the identification of inquiry questions and the execution of information searches, leading to establishing learning achievement. Thirdly, the CIBO approach was more effective than the online learning support system combined with traditional learning in boosting learner perceptions and motivation. That is to say, using technological tools can significantly enhance the efficiency of inquiry-based learning conducted in a collaborative setting [67–69]. Students' perceptions of the learning environment, levels of motivation, and learning strategies all impact how they approach online education pedagogy [70–73]. This study highlights the significance of universities and educators considering these factors when designing and implementing online learning platforms and courses to provide students with a more engaging and productive learning environment.

VI. Conclusion

This study has identified the most pertinent subject within a collaborative inquiry-based online system that aims to enhance individual and peer-supported programming methodologies. In computer science education, the efficacy of conceptual learning, students' perceptions of the learning environment, and their motivation to learn are central concerns. Based on the results, online learning centered around collaborative inquiry has the potential to serve as a viable substitute for traditional teaching approaches and increase student engagement in the learning process. Additionally, it provides educators, curriculum developers, and education policymakers with indispensable guidance.

VII. Limitations and Future Work

While this study reveals the efficacy of the CIBO system in improving learning outcomes, perceptions, and motivations compared to conventional online learning, several limitations must be acknowledged. Firstly, the study focused on an introductory programming language, HTML and PHP. Future research should explore the adaptability of the CIBO system across various programming subjects and different levels of complexity. Secondly, this investigation was limited to a single course within a single semester in a university setting. Therefore, it is imperative to investigate the long-term impact, including the retention of programming skills and practical application in real-world scenarios in subsequent research. Additionally, future studies should include larger and more diverse sample sizes, encompassing students from various universities, countries, and cultural backgrounds. A broader sample can help generalize findings and uncover potential cultural or regional variations in the effectiveness of the approach. It is also essential to consider factors such as students' prior programming experience, motivation, and interest, as these may influence outcomes. Lastly, the CIBO system relies exclusively on text-based materials. To enhance the collaborative inquiry-based learning experience, research should explore the integration of advanced technologies such as AI, VR, and AR. This limitation could involve using AI-based approaches or generative AI tools to tailor tasks based on students' skill levels, while VR and AR can offer immersive, hands-on programming experiences.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Patcharin Panjaburi validated the instruments needed for needs analysis and assessment questionnaires. Krittawaya Thongkoo and Kannika Daungcharone conducted research in universities. Krittawaya Thongkoo wrote the paper. All authors had approved the final version.

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