Enhancing Information Communication Technology Competency in Thai University Student Computer Education Courses

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This study's objectives were to: 1) develop an integrated teaching approach using problem-based learning (PBL) to enhance information communication technology competency (ICTC) in 3rd-year Thai university Computer Science Studies students, 2) to evaluate the teaching approach, and 3) to compare learning outcomes before and after implementing the approach. The teaching approach comprised eight steps, including 1. Creating a brain-stimulating learning environment, 2. Dividing learners into small groups, 3. Integrating students into groups based on their abilities, 4. Defining problem situations, 5. Structuring the problem-solving processes, 6. Problem linkage, 7. Confronting problems, and 8. Checking for correctness. The learning effectiveness of the ICTC Model's course implementation had a pre-test mean = 16.70, SD = 1.78, and a post-test mean = 23.00, SD = 2.64, with a statistical t-test value of 8.81. These results indicated that learning outcomes significantly improved after implementing the teaching approach (p<.05) with 20 students. This research contributes to developing an effective instructional method to enhance ICT competencies in Computer Science education.

Keywords: *ICT competency, digital literacy, problem-based learning, remedial teaching model, Thailand*

INTRODUCTION

The digital age is an era of technological convergence characterized by the complexity of integrating personal skills with technological advancements (Tyner, 2014). These rapid changes have also transformed almost all fundamental aspects of human life. To meet these challenges, numerous studies and reports have discussed the critical nature of learning and using 21st-century skills, with experts commonly dividing these skills into three main groups, including fundamental learning skills, digital literacy skills, and life skills.

In Thailand, 21st-century skill development has long been critical in developing digital knowledge workers and lifelong learning skills (Charungkaittikul & Henschke, 2014). Studies have also reported on these skills' importance in enhancing analytical thinking skills (ATS) (Chinchua et al., 2022), critical thinking skills (CTS) (Dural et al., 2019), creativity development (Watnayoo et al., 2019), and computational thinking (CT) and coding skills (Aumgri & Petsangsri, 2019; Günbatar, 2020).

By applying conveniences in daily life together with technological design, problem-based learning can promote both progressive thinking and scientific progress. If learners can practice and learn through project-based learning (PBL), it will lead to better learning outcomes (Lin & Chen, 2023). Using problem-based learning techniques can promote collaborative learning, exchanging ideas between learners, and receiving instructor guidance, resulting in better learning effectiveness than traditional learning methods. PBL can also deepen learners' understanding, increase learning motivation, help develop self-directed learning abilities, and improve problem-solving skills by seeking knowledge (Al-Qora'n, 2023).

The Covid-19 pandemic has impacted both online and offline education. Recently, various studies have come out concerning the effectiveness of online learning and teaching pedagogies, including blended learning, problem-based learning, self-directed learning, and student-centered learning using flipped classrooms and online learning (Leary et al., 2019). Central to many studies was the tested effectiveness that PBL brought to student learning as it stimulated effective learning and the interaction between instructors and learners (Guzmán-Ramírez & García, 2013; Kristianto & Gandajaya, 2023).

Remedial teaching involves employing targeted strategies to address individual learning needs and enhance students' technological skills when teaching ICT competency. By utilizing concepts such as individualized instruction, small group learning, and differentiated approaches, educators can provide personalized support to students who may require extra assistance. This may include adapting learning materials, breaking down complex concepts, and incorporating multisensory instruction to improve comprehension and engagement (Guzmán-Ramírez & García, 2013). Continuous assessment and feedback, along with providing remedial resources and personalized learning plans, further contribute to students' progress. By applying remedial teaching concepts, educators can ensure that all learners have the chance to develop their ICT competencies effectively.

The curriculum framework set by the Thai Ministry of Education (2008) requires teachers to have various knowledge standards, particularly in promoting thinking skills and self-learning strategies. Other pillars include online and distance education tools with innovation and technology at the center of teaching and learning (UNESCO, 2020). This includes knowledge of concepts, theories, technology, and educational innovation that enhance learner development, problem analysis, and innovation improvement for continuous learning. Educators must also be well-versed in evaluation skills and can analyze, synthesize, and assess knowledge with technology and know-how in self-development and learning management (Chardnarumarn, 2021).

Therefore, ICT competencies must encompass fundamental knowledge in technology, using technology for communication, accessing and evaluating information, information management, producing and creating information communication media, ethics in using ICT, and using ICT for communication to enhance work performance and develop competency in practical work. As such, fundamental knowledge of technology is especially critical.

These ICT competency skill sets are supported in a study from Thailand in which Thai student-teacher ICT competency was judged by the student-teachers themselves as their programming skills, followed by their digital media skills, and finally, their overall ICT knowledge (Chardnarumarn, 2021). In another Thai study, the author examined 377 teachers and their perceptions as to what was needed for teachers to achieve ICT competency (Akarawang et al., 2015). Not surprisingly, the teachers indicated they needed training focused on practical skills. hey also voiced the need for better training guidelines, and proper instructor needs assessments. Finally, blended training methods could effectively combine traditional lecture-based and internet-based training.

Typically, ICT competencies for Thai students in computer education and programming consist of computer system design, educational system design, and programming. Through surveys of opinions from Thai instructors in computer education-related disciplines, the most critical competency for computer education students was determined to be computer system design (Chardnarumarn, 2021). Furthermore, ICT competencies were divided into five aspects: knowledge, skills, self-perception, personality traits, and attitudes. Moreover, the personal skills of technology and communication education personnel can play a significant role in student competencies (Guzmán-Ramírez & García, 2013).

LITERATURE REVIEW

Learning Environment

The learning environment refers to the physical and abstract conditions surrounding the learners. The physical aspect includes the classroom environment, such as size, layout, lighting, and seating arrangements, as well as the external environment outside the classroom, such as computer science laboratories or language labs.

The abstract aspect of the learning environment includes instructional management, psychological atmosphere, and emotional ambiance, which directly influence learners positively and negatively, ultimately impacting their learning efficiency and outcomes. The learning environment and classroom management design aim to enable learners to achieve desired learning outcomes and acquire knowledge, skills, and desirable qualities. Designing a learning environment to support 21st-century skills requires a process such as the following:

Establish Learning Practices

This provides support from people and a physical environment that supports teaching and learning to achieve skill-based outcomes in the 21st century.

Support a Professional Learning Community (PLC)

PLCs enable students to collaborate, share best practices, and integrate 21st-century skills into classroom practices (DuFour & Eaker, 2009). In Thailand, Tanyarattanasrisakul (2017) added that PLCs are effective if teachers and community stakeholders work together as a caring community sharing mutual values and visions with each other. Additionally, it was determined that there is a need for teacher leadership and collaboration within the PLCs if the PLC is effective in teaching 21st-century skills.

Facilitate Real-World Learning Experiences and Projects

These allow students to learn within the context of the 21st century.

Provide Access to High-Quality Technology Tools and Group Learning Resources

Each student has different learning goals and backgrounds. As such, their learning environments must be organized according to the individual learner's aptitudes, needs, interests, and goals through surveys that evaluate their aptitudes, needs, interests, and goals for learning (Twyman, 2018). Teacher flexibility is then required to create diverse learning styles to meet each student's potential.

Remedial Teaching

Remedial teaching refers to providing additional activities or experiences to students learning according to the regular teaching methods during class time, similar to most students. However, these students need help to achieve the learning objectives set by their teachers. The purpose of remedial teaching is to allow these students to spend more time on additional studies and modify the learning methods to help them achieve the desired learning objectives. It also prepares them for further learning or determines if they have met the criteria for passing the subject (Ministry of Education, 2008).

There are various formats of remedial teaching, such as using educational games to make learning enjoyable and challenging, providing opportunities for student participation in the classroom, and allowing them to solve problems independently. Typically, a review of previous knowledge is presented, followed by introducing new content through drill and practice activities and testing exercises until the students can comprehend the lesson.

In developing ICT competencies, remedial teaching concepts can be applied to address specific learning needs and support students who may require extra assistance. Here are some potential remedial teaching concepts that can be utilized:

Individualized Instruction

Individualized instruction tailors the instruction to meet the specific learning needs of each student. This can involve providing additional practice exercises, offering alternative explanations or demonstrations, and adapting the learning materials to accommodate different learning styles.

Small Group Instruction

Small group instruction conducts targeted instruction in small groups to provide focused attention and address specific areas of difficulty. Group activities facilitate peer learning and collaboration, allowing the teacher to provide individualized support.

Differentiated/Student-Centered Learning

This form of learning modifies the content, process, or products of learning to suit the diverse needs of students. This can involve providing alternative assignments or projects that cater to different levels of understanding and skills. Make every effort to 'personalize' the learning process to achieve the goals set (Twyman, 2018).

Scaffolded Learning

Scaffolded learning breaks down complex tasks or concepts into smaller, manageable steps. It is also a method in providing guided practice, support, and feedback in helping learners slowly develop their comprehension and skills in ICT. An excellent example of scaffolding and PBL working in combination is a study by Simons and Klein (2007), who used a hyper-media program with students in a problem-based situation (flying around the world in a balloon). Students who used scaffolding options performed significantly better than students with no scaffolding support, which the authors' suggested enhances inquiry and performance.

Multisensory Instruction

Multisensory instruction incorporates multiple senses in teaching and learning activities to enhance comprehension and retention. This can involve using visual aids, hands-on activities, audiovisual materials, and interactive technologies such as gamification and virtual realities (VR) to engage students and reinforce learning (Poondej & Lerdpornkulrat, 2019; Sarapak et al., 2022).

Continuous Assessment and Feedback

This is an ongoing process that regularly assesses students' progress and provides constructive feedback to identify areas for improvement. This can help guide remedial teaching efforts by targeting specific weaknesses and addressing misconceptions promptly.

Remedial Resources and Materials

Remedial resources and materials provide supplementary resources, such as remedial worksheets, interactive online tutorials, educational software, or reference materials, to reinforce learning outside the classroom and allow students to practice at their own pace.

Personalized Learning Plans

Personalized learning plans are used to develop individualized learning plans that outline specific goals, strategies, and resources tailored to each student's needs. These plans can be regularly reviewed and adjusted based on ongoing assessment and progress. Strong support for personalized learning comes from the International Association for K–12 Online Learning (iNACOL), whose belief is that *personalized learning* tailors learning to each student's strengths, interests, and needs. Additionally, iNACOL believes individuals should have a '*voice and choice*' in where, how, and what they learn. In this environment, instructors act as facilitators who create flexible learning processes through online learning (Friend et al., 2017). However, another study has indicated that the implementation of personalized learning is met with slow implementation in traditional formal schools with classrooms only (Gross et al., 2018).

By incorporating these remedial teaching concepts into the development of ICT competencies, educators can better support students with varying learning abilities and ensure that all students have opportunities to succeed in acquiring essential technology skills.

Problem-Based Learning (PBL)

Teaching PBL online requires careful planning and implementation to ensure effectiveness. Based on the literature's review, the following might be considered effective methods for teaching PBL online:

Clear Learning Objectives

Clear learning objectives communicate the learning objectives and outcomes of the PBL activity to students. This helps them understand their goals and stay focused throughout the online session. Students are encouraged to brainstorm with group members to accomplish each project's learning objectives through small project groups (Chinchua et al., 2022; Nilsook et al., 2021).

Well-Structured Online Platforms

Well-structured online platforms facilitate student collaboration and interaction. This could be a campus-wide environment learning management system (LMS) such as Moodle or an Internet cloud-based system such as Google Classroom. Also, educators should be aware that some LMS tools might require significant technical support for training and support (Pimdee et al., 2023). Therefore, ensure this is allowed in the budget and supported by school administrators.

Teachers Act as Facilitators

Teachers act as facilitators to actively guide and support students throughout the PBL process (Friend et al., 2017). Facilitators are expected to provide clear instructions, offer resources, and monitor the progress of student groups. Teachers should be available for questions and provide timely feedback.

Group Dynamics

Group dynamics is a process where students are assigned to small groups which establishes clear roles and responsibilities within each group. It also encourages effective communication and collaboration among group members through online discussions, video conferences, or virtual meetings.

Authentic Problems

Authentic problems is involved with the selection of authentic and relevant problems that encourage critical thinking and problem-solving skills. These problems should reflect real-world situations and allow for multiple perspectives and solutions.

Resource Availability

Resource availability should ensure student access to necessary online resources and materials. It should also provide learners with relevant readings, case studies, articles, videos, or simulations that support their exploration and understanding of the problem.

Reflection and Debriefing

Reflection and debriefing is undertaken after the PBL session by allowing students to contemplate on their learning experiences, evaluate their problem-solving strategies, and share their insights with the group. This promotes metacognitive skills and enhances their learning outcomes.

Assessments

Assessments should be designed that align with the PBL approach. They are used to assess the process (e.g., group collaboration, critical thinking skills) and the product (e.g., problem-solving outcomes, presentations, reports). It is also necessary to give constructive feedback to assist students in improving their performance.

Similarly, Brockett & Hiemstra evaluated *self-directed learning (SDL)*. Their analysis concluded that SDL becomes effective when interactive environments and feedback channels are established, and assignment choices encourage meaningful and different learning experiences and resources.

Technology Support

Technology support should ensure students are comfortable using the online tools and platforms. Offer technical support and resources to troubleshoot any technical issues they may encounter during the PBL activities.

Continuous Improvement

Continuous improvement is a process which regularly evaluates and improves the online PBL process based on student feedback and outcomes. Teachers should incorporate modifications and enhancements to optimize the learning experience for future PBL activities.

By implementing these practical methods, educators can create a rich and engaging online learning environment for problem-based learning, fostering critical thinking, collaboration, and applying knowledge and skills.

Information Communication Technology (ICT) Competence

For numerous reasons, information communication technology (ICT) competence is critical in the digital age. These include:

Integration With Daily Life

Information communication technology has become deeply integrated into various aspects of our daily lives, including communication, education, work, entertainment, and commerce (Norman, 2016). Being technologically competent allows individuals to effectively navigate and participate in these digital domains, ensuring they can keep pace with the demands of modern society. Participation in a *digital learning ecosystem* (DLE) is also a path to technology competence (Chinchua et al., 2022) as a DLE integrates digital technologies and teaching management tools in a quest to achieve student 21^{st}-century learning goals (Gütl & Chang, 2008).

Economic and Professional Opportunities

The digital age has transformed nearly all national economies and created new professional opportunities. ICT competence opens doors to various careers and positions as organizations increasingly rely on technology to enhance employability and enable workers to adapt to rapidly evolving job markets. In Thailand, numerous studies and reports have elaborated on how ICT is now a critical pillar in Thailand's 4.0 vision for a new digitally enabled society (Ruenphongphun et al., 2022), with a vision of industry using the IoT (Internet of Things) to connect robotic assembly lines and their supply chains (Anuntarumporn & Sornsaruht, 2022; Rauch et al., 2021).

Communication and Collaboration

Information communication technology facilitates communication and collaboration on a global scale (Kanawapee et al., 2022). Competence in using digital tools, platforms, and communication technologies enables effective communication and collaboration with others, regardless of geographical barriers. It enables individuals to connect, share ideas, collaborate on projects, and engage in remote work or virtual teams using professional learning communities (PLCs) (Kanawapee et al., 2022; Tanyarattanasrisakul, 2017).

Access to Information and Resources

The Internet has revolutionized access to information and resources, with ICT competence allowing individuals to leverage digital tools and platforms to access vast amounts of knowledge, research, educational resources, and online learning opportunities (Kanawapee et al., 2022; Tanyarattanasrisakul, 2017). The Internet promotes self-learning, empowers individuals to acquire new skills, and facilitates lifelong learning through continuous personal and professional development ("The new normal is digital," 2021).

Efficiency and Productivity

ICT offers tools and systems that enhance efficiency and productivity. Being competent in utilizing these technologies enables individuals to streamline tasks, automate processes, organize and analyze data effectively, and make informed decisions. It enables individuals to work smarter, optimize workflows, and achieve higher productivity levels in various domains.

Innovation and Problem-Solving

Competence in ICT fosters a mindset of innovation and problem-solving. It equips individuals with the skills to leverage technology creatively, identify opportunities for improvement, and develop innovative solutions to complex challenges. It encourages critical thinking, analytical skills, and adaptability in a rapidly changing technological landscape (Aumgri & Petsangsri, 2019).

Digital Citizenship and Online Safety

In the digital age, information technology competence is essential for responsible digital citizenship and online safety information and engaging in responsible online interactions (Kerdtip & Angkulwattanakit, 2023). It includes understanding privacy and security concerns, practicing safe online behavior, and being aware of digital ethics (García-Umaña & Tirado-Morueta, 2018; Helsper & Smahel, 2020; Leekitchwatana & Pimdee, 2021). Competence in information technology empowers individuals to navigate digital spaces safely, protect their personal information, and engage in responsible online interactions (Purnama et al., 2021; Ruenphongphun et al., 2021).

Additionally, Chardnarumarn et al. (2021) have added that teaching ICT competence also includes three main elements. These include basic computer knowledge (KNOW), system design, computer programming, educational media design and development (PROGRAM), and the design and development of electronic media for education (MEDIA). The components of computer system design include basic knowledge of the theory of computer systems, hardware and software, beneficial information technology for educational work, data types and formats, and data storage and management (Kendall et al., 2020). The principles of hardware and software operations, microprocessors, computer structure and components, memory units, logic circuits, control circuits, interfaces, IoT devices, computer assembly, types and formats of operating systems, and database usage are also essential (Sinclair, 2017).

ICT competency also involves basic computer problem-solving abilities, appropriate installation of operating systems, types and formats of operating system usage, roles and responsibilities of operating systems, allocation of processing units, installation of operating systems and peripherals, problem analysis methods, maintenance, and computer repair.

In summary, ICT competence is vital in the digital age because it enables individuals to effectively engage with technology, access opportunities, communicate globally, enhance productivity, foster innovation, and navigate the digital landscape responsibly. It empowers individuals to thrive in the digital era and contribute to the advancement of society.

Study's Objectives

1. To develop a blended learning approach that integrates problem-based learning to enhance the technological competencies in information technology for students in the Computer Science curriculum.

2. To evaluate the effectiveness of the blended learning approach that integrates problem-based learning to enhance the technological competencies in information technology.
3. To compare the learning outcomes and performance in designing and developing educational hardware devices using the blended learning approach that integrates problem-based learning to enhance the technological competencies in information technology for students in the Computer Science curriculum before and after the course.

METHODS

The conceptual model was developed after a review of the literature. Subsequently, the researchers presented the model, the teaching plan, and the assessment test to seven experts to advise on the course material's quality, clarity, and usability. Twenty students were selected for the course, from which a 30-item ICT competency pre-test was administered. After course completion, a 30-item ICT competency post-test was administered.

Additionally, all the experts were active Thai university educators. The experts' opinions were judged using the index of item objective congruence (IOC). The IOC evaluation values ranged from 0.86 to 1.00 for each item. These indicated that the components of the teaching plan were consistent, with improvements made according to expert suggestions. After evaluation, the student pilot test used a 5-level rating scale with an average item value of 3.51.

Sample

The sample used in this research were 20 third-year Thai university students enrolled in a three-credit-hour *Design and Development of Educational Hardware Devices* class at Phetchaburi Rajabhat University. The study was undertaken in the second semester of the academic year 2022 for five weeks, four hours per week (20 hours total). The researchers conducted the learning model and collected the data.

Study Variables

The primary variable was a remedial teaching model combining problem-based learning designed to enhance ICT competency for students in computer science education courses. The dependent variables were learning achievement and ICT competency in computer system design, education, and programming.

Research Tools

The primary research instruments used for the study consisted of three elements. These included 1) teaching plans based on the remedial teaching model incorporating problem-based learning to enhance university student ICT competency in computer science education courses, 2) achievement tests, and 3) an ICT competency test.

The Remedial Teaching Model Incorporating Problem-Based Learning Lesson Plans

The steps to create the class lesson plans were as follows:

Identification of the Learning Objectives and Course Description

Step 1 was used to determine the specific ICT competencies students needed to develop and what learning outcomes the computer science undergraduate students were expected to reach by completing the five-week course.

Assessment of Students' Needs/ICT Competency

Step 2 involved conducting a diagnostic assessment to identify each student's existing knowledge and skill gaps. The results were then analyzed to determine areas where students required remedial instruction.

Selection of Appropriate Problems

Step 3 involved selecting real-world problems or scenarios relevant to the students' lives, and the course objectives were developed. Every effort was made to ensure the problems were challenging but achievable at the student's current level of ICT knowledge.

Learning Activity Design

Step 4 used scaffolding techniques, whose selected problems were broken down into smaller tasks or steps that students solved. Each activity was intended to guide the students through problem-solving while incorporating ICT tools and resources.

Instructional Resource Provisioning

Step 5 involved curating online and library resources. These included YouTube channels such as *Khan Academy* and *code.org* for coding and computational thinking. Computer hardware-focused sites such as *Computerphile* and *Crash Course Computer Science* were also examined. Lessons were selected for their Thai language content or English or Thai subtitles when possible. Suitability assessment was problematic as the course was designed for remedial learners, so adding the stress of another language was considered when the channels and their courses were selected.

Assessment Strategies Development

Step 6 involved the design of formative and summative assessments aligned with the learning course learning objectives. These included individual and group assessments that evaluated the students' problem-solving skills, ICT competency, and knowledge acquisition skills.

Incorporation of Remedial Strategies

Step 7 identified specific remedial strategies based on the diagnostic assessment results. Based on these results, differentiated instruction plans were developed to address each student's needs, such as additional tutorials or practice exercises. Answers to practice quizzes were made available, as well as the worksheets for ongoing review. Once again, language considerations were in focus when using online resources.

Collaborative Learning Opportunities

Three levels of learners were assessed from the assessment process in Step 2. When and where possible, these students were integrated so students could work collaboratively on problem-solving tasks. This fostered teamwork, communication, and critical thinking skills through group discussions and projects. Strong support for Step 8 is found in the literature, with Yildiz and Gündüz (2020) determining that peer instruction has a positive and significant effect on secondary school computer programming teaching and student programming self-efficacy (PSE). The authors also indicated that peer instruction positively affected student PSE perceptions, which was greater than traditional teaching methods.

Reflection and Feedback

Multiple studies have indicated the importance of Step 10's reflection and feedback process (Yangsompoi et al., 2021). As such, sufficient time must be allocated for learners to review their learning experiences and problem-solving approaches. Instructors are expected to provide feedback on student progress, addressing their strengths and areas for improvement.

Review and Revise/Performance Assessment

Step 11 involved continuously evaluating the effectiveness of the ICT competency course lesson plans based on student performance and feedback. This step is critical in the refinement as it enhances student learning outcomes. Performance assessment forms are helpful at this step.

Pilot Test/Tryout

The remedial teaching plan incorporating problem-based learning after the expert assessment was given to a group of students who were not participants in the final study. Based on their input on reliability and internal consistency using Cronbach's Alpha Coefficient formula, the value was between 0.72-0.86, which passed the established confidence criterion.

Achievement Test

The following represents the steps in creating and validating the study's test to measure learning outcomes for the ICT competency course developed for the Bachelor of Education Program in Computer Science at Phetchaburi Rajabhat University.

Five learning objective components were developed from the analysis of the indicators and learning outcomes used within the computer science curriculum. These included mathematical computations in computer science, hardware systems and connections, software usage with hardware devices, and using commands with sensors to display computer results.

Subsequently, the research team reviewed the completed test used to measure learning outcomes for content validation, appropriateness assessment, content accuracy, and suitability. From the meeting, recommendations for improvement and modifications were made and implemented.

The test was then presented to seven academic experts to assess the content's accuracy and the competencies of the items it aimed to measure. The experts' opinions were judged using the Index of Item Objective Congruence (IOC). The IOC evaluation values ranged from 0.86 to 1.00 for each item.

Based on the feedback from the experts, the test was revised and modified. It was then administered to students in different learning groups to analyze the items' level of difficulty (p) and discrimination power (r). Items that exhibited appropriate difficulty and discrimination power were selected to ensure the reliability of the test. The KR-20 formula by Kuder-Richardson was used to calculate the test's internal consistency reliability, yielding a reliability coefficient of 0.81.

The KR-20 formula calculates the degree of agreement or consistency among the items in the test. It estimates how well the items measure the same underlying construct or attribute being assessed and uses coefficient ranges from 0 to 1, with higher values indicating greater internal consistency and reliability.

The resulting KR-20 coefficient represents the estimated internal consistency reliability of the test. It indicates the extent to which the items in the test measure the same construct consistently. It is worth noting that the KR-20 formula assumes that the items are independent and that the test is unidimensional, meaning it measures a single construct. If the test contains multiple dimensions or item dependencies, alternative reliability measures such as Cronbach's alpha may be more appropriate. The final version of the test was then used on a pilot-test sample group.

Problem-Based ICT Competency Test

The following represents the steps in creating and validating the study's test to measure ICT competency using a problem-based approach for the ICT competency course developed for the Bachelor of Education Program in Computer Science at Phetchaburi Rajabhat University. Relevant documents on measurement and evaluation methods were examined. The test assessed five learning components: problem-solving, brainstorming, information perception, analysis, and knowledge application.

Subsequently, the research team reviewed the completed test used to measure learning outcomes for content validation, appropriateness assessment, content accuracy, and suitability. From the meeting, recommendations for improvement and modifications were made and implemented.

The test was then presented to seven academic experts to assess the content's accuracy and the competencies of the items it aimed to measure. The experts' opinions were judged using the Index of Item Objective Congruence (IOC). The IOC evaluation values ranged from 0.86 to 1.00 for each item.

Based on the feedback from the experts, the test was revised and modified. It was then administered to students in different learning groups to analyze the items' level of difficulty (p) and discrimination power (r). Items that exhibited appropriate difficulty and discrimination power were selected to ensure the reliability of the test. The KR-20 formula by Kuder-Richardson was used to calculate the test's internal consistency reliability, yielding a reliability coefficient of 0.80.

Learning Environment: Blended Teaching Approach for ICT Competency Development in Computer Science Curriculum

To study ICT competency, the researchers analyzed relevant documents, research papers, and articles on the ICT competency of teachers, educational personnel, and school administrators. The analysis aimed to identify published articles on the ICT competency of undergraduate computer science students, specifically the components used in confirmatory factor analysis (CFA). Additionally, the review examined the components of the learning environment and the blended teaching approach, which incorporates problem-based learning to create a learning model.

The learning environment development follows a blended teaching approach that integrates problem-based learning. The developed environment was then presented to seven experts for evaluation. This evaluation aimed to assess the lesson's quality and make necessary improvements and modifications.

The developed learning environment was implemented with a sample group of students. This involved applying a blended teaching approach that incorporates problem-based learning. This implementation aimed to observe the learning environment's effectiveness and make any further adjustments.

Data Analysis

Analysis was conducted on computer system design in education and programming. The learning approach was a blended learning model with problem-based learning to develop information technology competence (ICTC Model). The research also included measuring learning effectiveness using pre-built software programs to calculate statistical values such as percentages, means, and standard deviations (SD). These values were then compared against the established criteria, which required learners to achieve an average score greater than 70%.

RESULTS

Problem-Based Learning (PBL) and Brainstorming Learning

Brainstorming and PBL are teaching methods that use problems as a foundation. They stimulate students' curiosity, eagerness to learn, and exchange of ideas to solve problems. The focus is empowering students to seek knowledge, with the teacher providing guidance and arousing their interest in identifying and understanding the problems. Researchers have summarized the seven steps of PBL as follows:

1. Students are at the center of authentic student-centered learning.
2. Divide students into small groups of approximately 5-8 individuals.
3. The role of the teacher is to facilitate and provide guidance
4. Utilize problems as stimuli to promote learning.
5. Problems should be complex and ambiguous and allow for various solutions.
6. Students become problem solvers by seeking new information independently (self-directed learning).
7. Assessment is based on authentic assessment, considering the students' abilities and performance during the learning process and the resulting learning products.

Therefore, problem-based learning is a learning approach that opens opportunities for learners to practice critical thinking, self-directed learning, and the application of knowledge. It ensures that the acquired knowledge or skills are durable and transferable to new situations.

ICTC Model for Integrating Problem-Based Learning to Develop ICT Competencies

From the study's analysis, the final ICTC Model was determined to consist of eight steps, including:

Creating a Brainstorming Learning Environment

The instructors organized the learning environment into small groups and equipped each group with hardware devices while explaining how to use the sensors and hardware devices.

Dividing Learners Into Subgroups

The instructors assessed each learner's learning performance through a pre-learning test using an e-learning system. Based on the test scores, the learners were divided into subgroups according to their high, medium, and low abilities.

Combining Abilities Within Groups

The instructor assigned learners to specific subgroups based on their high, medium, or low abilities.

Defining Problem Situations

Each group was presented with problem situations to analyze and solve. The instructors defined the problem situations and assigned each group hardware devices to solve the problems. The instructors also explained the characteristics of the hardware devices, how to use their sensors, and how to connect their sensors. Basic programming instructions were reviewed to control the device's operations. The instructors then assigned each group one problem to solve. The learners analyzed and broke down the problem into parts using the provided problem situations and their hardware devices. Group problem analysis made use of Google Docs for collaboration.

Problem-Solving Structure, Patterns, and Formats

Learners identified patterns and wrote problem-solving formats using hardware devices based on the given problems. The instructors provided suitable guidance.

Linking and Summarizing Problem Analysis

Learners reviewed and summarized the essential issues related to the problems using hardware devices. They linked and summarized the problems and proposed appropriate solutions. Learners considered similar parts of the problem-solving process and eliminated unnecessary parts using Google Docs.

Problem-Solving Engagement

Learners experimented by connecting circuits and writing control programs to solve each part of the problem. They considered what was necessary for problem-solving.

Checking Accuracy

Learners verified the accuracy of their solutions. The instructors provided suitable guidance and checked the results' correctness according to the problems' requirements. Learners assisted in testing the hardware device's performance and summarized the teaching process. Each group representative presented their problem-solving ideas and discussed hardware device usage, programming, and circuit results.

Figure 1 depicts the research model for ICT competency development. Table 1 details the results from the expert opinions regarding the suitability of the blended learning approach with problem-based learning eight-step training session aimed at developing ICT competencies. Overall, the ICTC Model for the ICT competency course had an average score of 4.43 and a standard deviation (SD) of 0.56.

TABLE 1
ICTC MODEL SUITABILITY AND CONSISTENCY RESULTS

Steps	Activity	mean	SD	level
1	Creating a brain-stimulating learning environment	4.29	0.76	strongly agree
2	Dividing learners into small groups.	4.14	0.69	agree
3	Integrating students into groups based on their abilities.	4.29	0.49	strongly agree
4	Defining problem situations.	4.57	0.53	strongly agree
5	Structuring the problem-solving processes.	4.29	0.49	strongly agree
6	Problem linkage.	4.57	0.53	strongly agree
7	Confronting problems.	4.57	0.53	strongly agree
8	Checking for correctness.	4.71	0.49	strongly agree
	average	4.43	0.56	strongly agree

FIGURE 1
PROPOSED ICTC MODEL

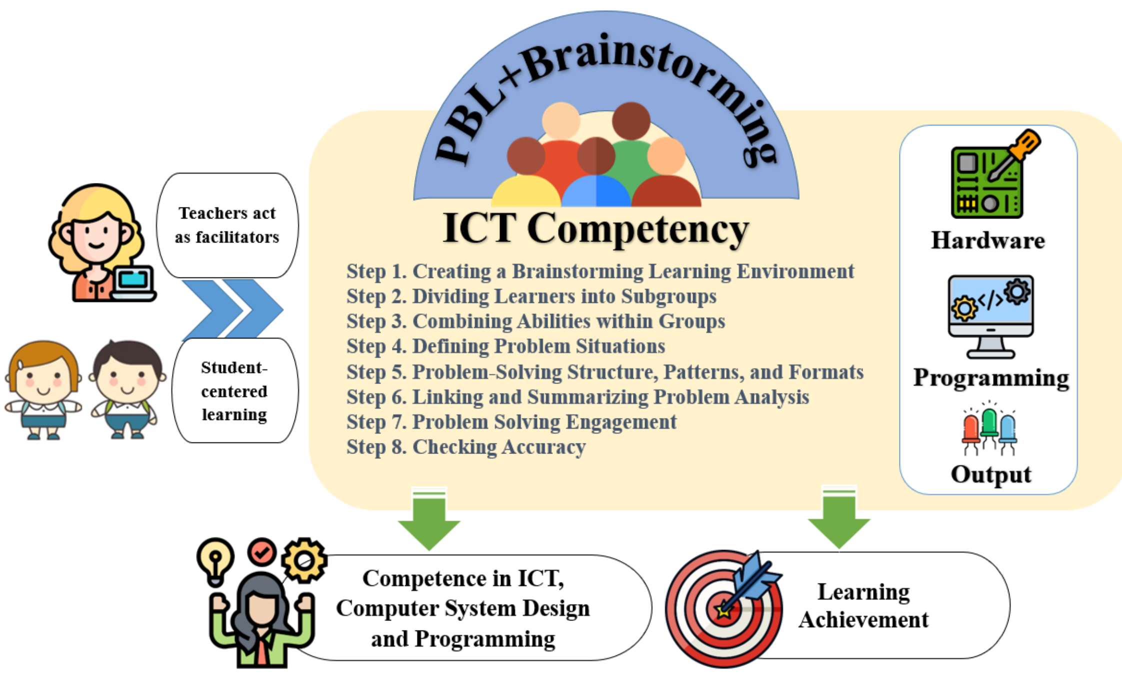

Table 2 shows the learning effectiveness of the ICTC Model's implementation in the *Designing and Developing Educational Hardware Devices* course. The dependent t-test analysis was conducted between the pre-learning and post-learning stages. It was determined that the score averages of learning effectiveness after the course were significantly higher than before the course, with a significance level of .05. Specifically, the pre-test mean = 16.70, SD = 1.78, and the score after learning was mean = 23.00, SD = 2.64, with a statistical test value of 8.81.

TABLE 2
PRE-TEST AND POST-TEST RESULTS

Assessment	N	Items	$\bar{x}$	Standard deviation	t-test	Significance
Pre-test	20	30	16.70	1.78	8.81	.00*
Posttest	20	30	23.00	2.64		

DISCUSSION

The blended learning approach using problem-based learning as a foundation received a high overall appropriateness in evaluating the ICTC Model teaching format, which targeted ICT competencies for students in a Thai Computer Science program. This result was achieved because the researchers synthesized teaching and learning management using the knowledge construction theory from various research studies. The design of the instructional activities followed a systematic approach, where each step had a relationship and was categorized as easy, moderate, or difficult. Problem situations were utilized to encourage students' active group participation, promoting collaborative learning and knowledge exchange. Furthermore, students could search for additional information from the Internet to collectively address and solve problem situations.

The evaluation results of the *Designing and Developing Educational Hardware Devices* course were based on input from seven academic experts who indicated that it was highly appropriate and consistent. These opinions were determined by using the Item-Objective Congruency (IOC) index, which ranged from 0.86 to 1.00 for each criterion, demonstrating a consensus among experts regarding the components of the eight-step teaching and learning model.

The ICTC Model steps included 1) Creating a brain-stimulating learning environment, 2) Dividing students into subgroups, 3) Combining abilities within the groups, 4) Defining problem situations, 5) Structuring and solving problems using hardware devices, 6) Linking problem-solving reviews and identifying key issues using hardware devices, 7) Engaging in creative problem-solving experiences using hardware devices, and 8) Verifying the system's operational accuracy.

Learning outcomes for the *Designing and Developing Educational Hardware Devices* used a blended learning approach with PBL as a foundation, and the information technology competence of students in the Computer Science program has improved. After the course, students achieved an average learning outcome score of 23.00 or 76.67%, higher than their pre-course average score of 16.70 or 55.67%. This improvement can be attributed to the student's engagement in the problem-based learning approach, which emphasizes hands-on practical tasks and collaborative teamwork. It also allows students with different skill levels to exchange ideas, break down problems into sub-problems within their groups, and link real-world issues with knowledge.

Furthermore, students actively seek knowledge independently, leading to sustainable learning outcomes. They have successfully conducted experiments with hardware devices and programmed circuits to solve complete problem situations creatively. This approach aligns with the research of Jacko et al. (2022), who used IoT technology in conjunction with PBL teaching techniques and found that the majority of students achieved learning outcomes of over 70%. It also supports the findings of Crespí et al. (2022), who stated that problem-based learning is an effective technique for developing interpersonal communication skills and teamwork. The analysis and pursuit of knowledge have significantly contributed to the substantial improvement in learning outcomes.

CONCLUSION

The study developed an ICT competency teaching and learning model (ICTC Model) using blended learning techniques combined with problem-based learning to evaluate 3rd-year Thai university students enrolled in a *Designing and Developing Educational Hardware Devices* course. Brainstorming was also essential for students during each phase of the model's implementation. The teaching approach comprised eight steps, including 1. Creating a brain-stimulating learning environment, 2. Dividing learners into small groups, 3. Integrating students into groups based on their abilities, 4. Defining problem situations, 5. Structuring the problem-solving processes, 6. Problem linkage, 7. Confronting problems, and 8. Checking for correctness. The learning effectiveness of the ICTC Model's course implementation had a pre-test mean = 16.70, SD = 1.78, and a post-test mean = 23.00, SD = 2.64, with a statistical t-test value of 8.81. These results indicated that learning outcomes significantly improved after implementing the teaching approach ($p<.05$) with 20 students.

RECOMMENDATIONS

In the management of learning, utilizing a blended learning approach with problem-based learning as a foundation is recommended to develop information technology competence for students in the Computer Science program. Teachers should be supportive in assisting and facilitating learning, understanding the lessons, and implementing the planned teaching strategies. Furthermore, they should encourage students to actively participate in activities and take responsibility for assigned tasks, fostering successful learning outcomes. Establishing a positive interaction between students and teachers is essential, including encouraging problem-solving discussions that enhance students' knowledge and promote sustainable learning.

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