Thai Computer Studies Student Teacher Complex Problem-Solving Skills Development: A Cooperative Learning Management Model

Natchanun Sermsri
King Mongkut's Institute of Technology Ladkrabang

Aukkapong Sukkamart
King Mongkut's Institute of Technology Ladkrabang

Thiyaporn Kantathanawat
King Mongkut's Institute of Technology Ladkrabang

The research aim was to develop cooperative learning management (CLM) model using computational thinking (CT) and mind mapping techniques to promote Thai computer studies student-teacher (CSST) complex problem-solving skills (CPSS). The sample was 15 first-year CSSTs in the Faculty of Education's Computer Studies Department of Thailand's Thonburi Rajabhat University. The pre-study achievement test classified students into three levels (weak, moderate, or strong). Five experts were involved in the assessment of the CLM plan, which was determined to have a content validity index (CVI) at the highest level (mean = 4.00). They also evaluated the ***21*** *indicator rubric scoring-type test tool for complex problem-solving skills (CPSS) and determined its CVI mean = 3.99. After a pilot test of 30 student teachers, a 42-item questionnaire was finalized. The final CPSS course involved five primary components within an eight-step process. The CSST used six sessions of four hours each. Results showed that the final course post-test score was 90.40 for all 15 student-teachers, significantly higher than the 70% achievement level setting.*

Keywords: computer programming, information communications technology (ICT), pre-service teachers, Thailand

INTRODUCTION

Modern 21st-century economies and their digitally-enabled knowledge workers require skills in digital literacy, computational thinking (CT) (Prommun et al., 2022), programming skills (Chinchua et al., 2022), and higher-order thinking skills (HOTS) such as analytical thinking skills (ATS) and critical thinking skills (CTS) (Masapanta-Carrión & Velázquez-Iturbide, 2018; Pipitgool et al., 2021). As developing economies such as Thailand move into the fourth technological generation (Industry 4.0/Thailand 4.0), new industries will be created with new technologies using robotics and the Internet of Things (IoT) (Aumgri & Petsangsri, 2019), Duangpummes & Kaewurai, 2017; Durak et al., 2019; Hutamarn et al., 2017; Intaratat et al., 2021). As a result, people must adjust, transitioning from third-generation-related skills to 4th generation digital knowledge worker skills (Ruenphongphun et al., 2021).

However, if the obstacles are overcome, the rewards can be significant. The average wage for programmers in the United States is $93,000 a year, while computer and ICT system managers can average $156,390 per year (Bureau of Labor Statistics, 2021). In Thailand, computer programmers expect approximately 831,000 Thai baht (THB) per year, or 400 THB an hour (Economic Research Institute, 2022). They can also expect an annual bonus of about 32,000 THB.

Unfortunately, despite the relatively high Thai wages for computer programmers and ICT professionals, the International Labour Organization (ILO) has reported that the nation’s ICT workforce is a meager 1% (386,000) of the nation's entire workforce (ILO, 2019). The same ILO report indicated that Thailand, like India and Indonesia, had 33% of its ICT positions filled with women.

However, ICT has become a core pillar in Thailand’s 4.0 quests for a new digitally enabled society (Ruenphongphun et al., 2022), with a vision of robotic assembly lines connected to the IoT (Anuntarumporn & Sornsaruht, 2022; Digital economy, 2015; Rauch et al., 2021; Wongwuttiwat & Lawanna, 2018). Other studies are projecting that the value of Thailand's software sector will increase to $5.05 billion in 2022 (Statista Research Department, 2021). This is on top of Thailand's digital market value, which in 2020 was estimated at $19.24 billion. The numbers grow even further when one knows that Thailand’s expanding digital/Internet economy in 2021 exceeded $30 billion, up an astonishing 51% from the previous year (Leesa-nguansuk, 2021). By 2025, Thailand’s total ‘Internet economy’ is projected to reach $54 billion (e-Conomy SEA 2021, 2021).

Therefore, it seems that Thailand's growth is only limited by the availability of a highly-skilled workforce with 21st-century skills. As technology and the new digital economy explode, the programmer and ICT specialist needed to support it is growing at a snail's pace. This is despite government-mandated programs going back decades to develop Thailand's ICT-related personnel and the supporting infrastructure (Sermsri et al., 2021).

As we can see, ICT and programmer positions are well paid in their respective societies. Unfortunately, Thailand's yearly graduation pool of skilled individuals who can enter these job skills is limited. Various studies have reported on why this is, with consistent themes being the lack of student PSS (Bosse & Gerosa, 2017; Gomes & Mendes, 2007; Robins, 2019; Savage & Piwek, 2019), the lack of the needed metacognitive skills in the early phases of programming education (Ismail et al., 2010), the use of printed books which are ineffective (Bennedsen & Caspersen, 2005; Jenkins, 2002), and the lack of individual programming self-efficacy (PSE) (Compeau & Higgins, 1995; Erol, 2020; Gurer & Tokumaci, 2020; Kanaparan et al., 2019)), which is the learner’s belief that they can do a computer-related job. Finally, programming is more than just coding; it exposes learners to CT, which involves CPSS using concepts like abstraction and decomposition (Lye & Koh, 2014).

LITERATURE REVIEW

Computational Thinking (CT)

Computational thinking (CT) with multiple authors has determined positive relationships between the two, closely related to these topics, especially PSE. One such study was from Ozturk (2021), who evaluated student CT and PSE and determined that students' PSE improved when CT improved. Also, Durak et al. (2019) stated that PSS influenced CT, PSE, and robotics programming. Interestingly, the grade of the student also affected their CT and PSE. Günbatar’s (2020) examination of learner CTS and PSE also found that computer PSE was a significant predictor of CTS. Similarly, Yildiz and Gündüz (2020) found that peer instruction increased student PSE perceptions in computer programming classes better than traditional instruction methods.

Cooperative Learning Management (CLM)

Kövecses-Gősi (2018) has stated that today's learning environments need to consider the characteristics of a new digital generation. Moreover, these environments need to be experience-oriented and encourage teamwork-based cooperative education. As CLM is a process in which learning activities are used on learners with various abilities and knowledge, they work together in groups with the intention and willingness to take responsibility for their roles and duties while simultaneously solving complex problems. This is similar to ideas from Gardner and his Theory of Multiple Intelligence, in which he suggested that educators should learn as much as they can about whom they teach and stop trying to fit all learners through the eye of the same needle (Marenus, 2020).

In Thailand, Klinbumrung (2020) evaluated CLM's efficiency and use with engineering students and determined that CLM activities significantly and positively contributed to the group's overall learning achievement and course satisfaction. Also, in Thailand, the research team of Ratniyom et al. (2020) investigated how CLM combined with Learning Together (LT) and mind maps affected seven-grade student ATS and learning achievement. Results showed a significant improvement as well as higher student satisfaction.

Problem-Solving Skills (PSS)

With the above-mentioned 21st-century skills, *problem-solving skills* (PSS) have been consistently identified by employers as a vital prerequisite for employment. This is because it is an essential skill development skill needed in almost every industry sector (Durak et al., 2019). PSS is also essential in successful computer programming (Mathew et al., 2019). Cheah (2020) has pointed out in the study's literature review that computer programming is difficult to learn and master, with high global dropout and failure rates. Moreover, according to a literature review, one strong reason for these difficulties is the lack of PSS among computer programming students. Other studies have indicated that even though numerous tools are available that can assist in the teaching and learning of computer programming, the problems remain unresolved, which again is pointed out as students' lack of PSS (Bosse & Gerosa, 2017; Gomes & Mendes, 2007; Pillay & Jugoo, 2005; Robins, 2019; Savage & Piwek, 2019). Thus, computer programming is a complex subject that requires constant effort, a unique approach, and multi-layer skills (Cheah, 2020; Rößling, 2010).

In Thailand, the research team of Srakaew et al. (2021) used problem-based learning to develop a joint Thai/Japan education program for critical economic sector engineers. Using e-learning systems, Zoom face-to-face classes, and a form of the essential Japanese philosophy, '*monozukuri*,' the authors reported success in achieving the project's objectives.

Statement of the Problem

Problem-solving skills are a critical element in the success or failure of a learner's capability to be successful in computer programming. By extension, computer programming and related ICT skills are critical in Thailand's vision to achieve Thailand 4.0 and the related goals of developing digital knowledge workers. Success has vast rewards, with some estimates indicating that Thailand's total '*Internet economy*' could reach $54 billion by 2015.

However, there are not enough computer programmers or ICT specialists in Thailand, so ways must be found to overcome the multiple obstacles leading to choosing these careers and their ultimate success. Stating that Thailand's future competitiveness depends on it is not an understatement. Thus, the authors wish to create a cooperative learning management model in which computational thinking skills combined with mind mapping techniques can be used to increase Thai computer student teachers' complex problem-solving skills.

Research Objectives (RO)

RO1: *To create an effective collaborative learning management model that combines computational thinking and mind mapping to enhance Thai computer student teachers' complex problem-solving skills.*

RO2: *To evaluate the academic achievement after studying using the collaborative learning management model that combines computational thinking and mind mapping to enhance Thai computer student teacher complex problem-solving skills.*

RO3: *To study the assessment results on the collaborative learning management model that combines computational thinking and mind mapping to enhance Thai computer student teachers' complex problem-solving skills.*

METHODS

This experimental research study used a collaborative learning management method combined with computational thinking and mind maps. Computer student teachers from the Samut Prakan Campus of the Thonburi Rajabhat University were used to study complex problem-solving skills. The objectives were to measure their academic achievement and assess the results from using the proposed CPM Model after course completion.

Study Scope

This study is an experimental research study using a collaborative learning management method combined with computational thinking and mind mapping of computer student teachers attending Thailand's Thonburi Rajabhat University. The objective was to evaluate the student teachers' academic achievement and assess their complex problem-solving skills after using the CLM Model.

Sample Group

The sample group was 15 first-year computer student teachers in the Faculty of Education's Computer Studies department on the Samut Prakan Campus of Thonburi Rajabhat University.

Data Collection

The researcher provided six sessions of four hours each to enhance the complex problem-solving skills of 15 student teachers in computer studies at Thailand's Thonburi Rajabhat University. The pre-study achievement test classified students into three levels (weak, moderate, or strong). After that, the student teachers drew lots to determine who participated in the five groups (depending on level). A Rubric score system was then used to assess and measure the skills after each of the six sessions and the final course score in academic achievement.

Data Analysis

Analysis of fundamental index values such as mean and hypothesis testing used the one-sample t-test and t-test dependent statistics methods.

Research Tools

The CPM Model's suitability and conformity to the learning management process were evaluated by seven experts using five components (Table 1) (Chinchua et al., 2022; Ruenphongphun et al., 2022). These were: C1 - planning ability, C2 - self-control, C3 - information literacy, C4 - critical thinking, and C5 - knowledge application (Best, 1998; Sermsri et al., 2021).

The CPM Model's Steps

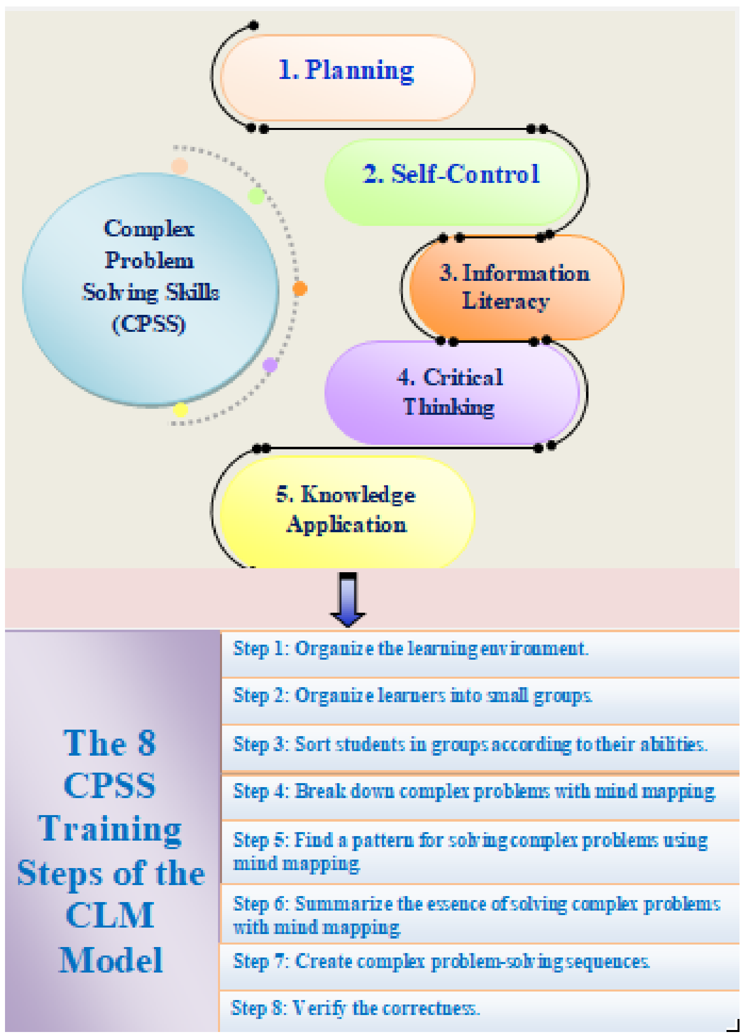
There are eight steps of cooperative learning management activities. These include Step 1 - Organize the learning environment, Step 2 – Organize learners into small groups, Step 3 - Sort students in groups according to their abilities from the pre-test, Step 4 - Break down complex problems with mind mapping, Step 5 - Find a pattern for solving complex problems using mind mapping, Step 6 - Summarize the essence of solving complex problems using mind mapping, Step 7 - Create complex problem-solving sequences, and Step 8 - Verify the correctness (Figure 1).

Figure 1 and Table 1 detail the CLM activities when computational thinking and mind mapping are combined to promote Thai student-teacher complex problem-solving skills. It was determined that a pre-test should be given to be effective, which rated each student as having weak, moderate, or strong skills. The student teachers were placed in one of the three groups from this process to break down the problem and find patterns using mind mapping techniques. After that, each of the three groups summarized their key points and wrote a sequence of steps with flowcharts to check the correctness of the proposed solution. However, if the proposed solution were incorrect, the group would repeat the steps to break the problem down until the correct solution was obtained.

The dependent variable included complex problem-solving skills, which consisted of 1)planning, 2) self-control, 3) information literacy, 4) critical thinking, and 5) knowledge application.

The content used in the experiment was 1) studying flowchart writing algorithms, 2) data types and variables, 3) control structures, 4) data input and display, 5) principles of programming using problem-solving skills, logical thinking, and problem analysis by programming methods, 5) practice programming in computer languages and 6) being able to create complex problem-solving programs.

FIGURE 1
THE COOPERATIVE LEARNING MODEL FOR CSST COMPLEX PROBLEM-SOLVING SKILLS DEVELOPMENT



RESULTS

Complex Problem-Solving Skills (CPSS) Components

Table 1 presents the 8-activity step complex problem-solving skill components as viewed from the opinions of the seven experts participating in the model's assessment. Overall, the suitability of the eight steps was assessed to be most appropriate. Also, Steps 1, 2, 5, and 8 were judged to be most appropriate, with a mean value of 4.71. Finally, component 2 corresponds to Steps 1-3, while Steps 4–7 correspond to components 1–5. Moreover, the last step is consistent with components 2 and 5.

CPM Management Plan Expert Assessment

The initial CLM Model and management plan were taken to five experts in teaching programming and specialized learning management techniques. Their input and use of an assessment questionnaire determined that the CLM plan's content validity index (CVI) was at the highest level (mean = 4.00). It was also determined that the consistency of the objectives of each learning management plan was at the highest mean as well, with an IOC = 1.00.

CPM Complex Problem Solving Skills Assessment

Five experts in teaching programming and technical learning management assessed the 21 indicator rubric scoring-type tool for complex problem-solving skills (CPSS). From this, it was determined that the CPSS evaluation questionnaire had a CVI = 3.99. It was also determined that the consistency of the objectives had an IOC of 0.80 – 1.00.

TABLE 1
RESULTS OF SUITABILITY ANALYSIS AND COMPLIANCE WITH CPSS (N=7)

Activity Steps	Solving CPSS Components					Suitability	
	C1	C2	C3	C4	C5	mean	meaning
Step 1 - Organize the learning environment		7				4.71	most appropriate
Step 2 - Organize students into small groups.		7				4.71	most appropriate
Step 3 - Sort students into groups according to their abilities from the pre-test.		7				4.57	most appropriate
Step 4 - Break down complex problems with mind mapping techniques.	7	7	7	7	7	4.57	most appropriate
Step 5 - Find a pattern for solving complex problems with mind mapping techniques.	7	7	7	7	7	4.71	most appropriate
Step 6 - Summarize the essence of solving complex problems with mind mapping techniques.	7	7	7	7	7	4.43	somewhat appropriate
Step 7 - Create complex problem-solving sequences.	7	7	7	7	7	4.57	most appropriate
Step 8 - Verify the correctness.		7			7	4.71	most appropriate
Overall average						4.61	most appropriate

CPSS Achievement Quiz

21 CPSS indicators were used to create 63 questionnaires on the course pre-test and post-test study achievement tests. Once again, from the input of five experts, the CVI mean = 3.54. However, from the

expert's assessment using IOC values, two items were determined to be below the 0.50 validity threshold and eliminated. This left 61 items for the next step, which was a pilot test of the questionnaire on 30 student teachers who were not participating in the 24-hour course. Results from the pilot test revealed that the instrument's quality had a Cronbach alpha confidence value of 0.86. The difficulty value used 55 exam items with an average value of 0.2 – 0.80 and the power to discriminate. The number of exams with an average between 0.2 - 1.00 is 44 items. The researcher has eliminated two items with the lowest average, so the number of practically usable exam items is 42.

Table 2 details the six learning unit results within the CPM plan, which combined *computational thinking* and *mind mapping* with *complex problem-solving skills*. Table 2 also shows that the final course score was 90.40 for all 15 student-teachers.

TABLE 2
THE CPM LEARNING UNITS AND FINAL POST-TESTING RESULTS

Module	unit name	$\bar{x}$	SD	t	*p*
1	Writing a program algorithm in sequence using flowcharts.	70.60	11.57	.12	.91
2	Writing a working algorithm of an alternative program with flowcharts.	88.20	9.83	4.14	.01*
3	Writing a working iterative program algorithm with flowcharts.	74.40	5.32	1.85	.14
4	Writing a working algorithm of a sequenced Python program.	87.40	4.56	8.53	.00*
5	Writing an algorithm alternative Python programming.	86.80	3.77	9.97	.00
6	Recursive and iteration Python writing to perform repetitive tasks with a typical pattern.	85.20	3.96	8.58	.00*
Post-testing Results		90.40	5.59	8.15	.00*

*Statistically significant at .05

Table 3 details the end-of-class student testing comparison results of the average assessment scores measuring complex problem-solving skills after studying with the *cooperative learning model* combined with *computational thinking* and *mind mapping* were significantly higher than the 70% threshold, which also had statistical significance at the .05 level.

Table 3 compares the students' learning achievement and each lesson's effectiveness results. Meguigans's formula and the learning results with t-test dependent were analyzed (Klinbumrung, 2020; Ruangsiri, 2020). Results revealed that average academic achievement scores before and after school were significantly higher than before at the .05 level. Also, the course effectiveness had a Meguigan mean score of 1.86, which was more significant than one and met the assessment criteria.

TABLE 3
PRE-TEST AND POST-TEST LEARNING ACHIEVEMENT AND COURSE EFFECTIVENESS

Testing	**Number**	$\bar{x}$	**SD.**	**t**	**p**	**Meguigans**
Before course	15	11.73	2.05	6.92	.00*	1.86
After course	15	16.93	3.39			

*Statistically significant at .05

DISCUSSION

The 15 student teachers' average scores from the 24-hour CPSS improvement course revealed that the mean achievement score in the course post-test was 7.89 points higher than before, with a statistical significance at the .05 level. Moreover, the course post-test score for all 15 students had a mean = of 90.40, which was statistically significantly higher than the 70% threshold at the .05 level. Furthermore, after studying Units 2, 4, 5, and 6, the mean was significantly higher than the threshold and was statistically significant at the .05 level. However, after studying Units 1 and 3, the mean scores were higher than the set criteria but not statistically significant at the .05 level.

Additional results revealed that the CLM Model was consistent with other studies investigating how to enhance complex problem-solving skills. Other elements from the study determined the following cooperative learning, computational thinking, and mind mapping.

Cooperative Learning

The study determined that even when each group of learners was arranged equally, there were differences in abilities within the group. This is consistent with Zamani (2016) in Iran, whose examination of learner cooperative learning and learning by differentiation of learners revealed that collaboration improves learner performance, whether working with classmates who are better or weaker. Thus, cooperative learning is particularly beneficial for low-level students.

Computational Thinking

Computational thinking involves breaking down problems from which problem-solving flowcharts are determined. Using this, the best path is selected, and a solution summary is used to create a sequence of algorithms to solve problems with symbols in the flow chart until a correct solution is found. CT is additionally useful for all majors, as it is helpful in our daily lives (Kroll & Laboskey, 1996).

This is consistent with research by Lye and Koh (2014), who examined 12th-grade student teaching and learning of computational thinking through programming. Their suggestion for effective CT instruction was to use a constructionism-based problem-solving learning environment. Other studies have also suggested Papert's *constructionist* educational approach for use in CT (Kroll & Laboskey, 1996; Lodi & Martini, 2021).

On the practical side, various authors have pointed out that CT skills can be achieved through blended learning and flipped classrooms, digital tools and platforms such as smartphones and social media, and management tools such as Schoology and Google Classroom (Eppard & Rochdi, 2017; Moto et al., 2018; Wang, 2010).

Also, learners can verbally describe their thought processes while coding with their on-screen programming activities. These thoughts and activities can then be recorded and analyzed later for feedback and qualitative data analysis.

Mind Mapping (MM)

Mind maps are used to help visually explain ideas. This allows learners to visualize breaking down a problem and finding a pattern to solve a problem.

This is consistent with Liu et al. (2018), who stated that MM could be an effective diagramming tool for computer programming visualization, structure, classification, and solving problems. As such, MM helps strengthen a learner's ability in logical and innovative thinking as well as helps in student motivation and lifelong learning.

Student-Teacher Learning Effectiveness

The CLM Model assessment results on student-teacher CPSS used the Meguigan formula, which has a criterion of 1.00 as a standard validity value. After measurement was conducted, student-teacher effectiveness was calculated to be 1.86, showing a high effectiveness correlation consistent with other studies using the Meguigan formula as a measurement tool (Klinbumrung, 2020; Ruangsiri, 2020).

Student-Teacher Academic Achievement

Student-teacher academic achievement had a significantly higher mean test score than before, at a statistically significant level of 0.05. This is consistent with multiple studies with a significant positive correlation between programming success and academic achievement (Gülmez & Özdener, 2015; Özdener, 2008).

Student-Teacher Assessment Results of CPSS

The results of the course completion assessment on student-teacher CPSS revealed that four modules had a mean score significantly higher than the rest at .05 (2, 4, 5, and 6), and Modules 1 and 3 were higher than the non-statistically significant threshold at .05, but overall after school was significantly higher than the set threshold (70%) at the .05 level.

This was consistent with research by Lye and Koh (2014), who indicated that programming classes could teach CT skills to high school seniors. Ki et al. (2018) added that university computer programming classes using mind maps could strengthen logical and innovative thinking.

CONCLUSION

The research objective was to develop a cooperative learning management model using computational thinking and mind mapping techniques to promote Thai student-teacher complex problem-solving skills (CPSS). The sample was 15 first-year student teachers in the Faculty of Education's Computer Studies Department on the Samut Prakan Campus of Thailand's Thonburi Rajabhat University. Five experts were involved in the assessment of the CLM plan, which was determined to have a content validity index (CVI) at the highest level (mean = 4.00). They also evaluated the 21 indicator rubric scoring-type test tool for complex problem-solving skills (CPSS). Again, it had a CVI mean = 3.99. After a pilot test of 30 student teachers, a 42-item questionnaire was completed. The final CPSS course involved five primary components, which could be developed using an eight-step process. The student teachers used six sessions of four hours each (24 hours total). The pre-study achievement test classified students into three levels (weak, moderate, or strong). A Rubric score system was then used to assess and measure the skills after each of the six sessions and the final course score in academic achievement. Results showed that the final course post-test scored 90.40 for all 15 student-teachers, significantly higher than the 70% achievement level setting. Using the Meguigan formula, student-teacher effectiveness was calculated to be 1.86, showing a high effectiveness correlation to the established 1.00 validity threshold.

IMPLICATIONS

1. The CLM Model can be developed into an online learning management system on various platforms when integrated with computational thinking and mind mapping.
2. Researchers can apply the achievement analysis and the assessment results of the CPSS model and compare it with other learning management styles that want to study the same skills.
3. Complex multidimensional problem-solving skills should be assessed, such as self-assessment and peer-to-peer assessment.

ACKNOWLEDGEMENT

The authors wish to thank Ajarn Charlie for his kind assistance in English language editing and proofing.

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