The Development of Problem-Based Learning and Concept Mapping Using a Block-Based Programming Model to Enhance the Programming Competency of Undergraduate Students in Computer Science

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Abstract **– The purpose of this research is to develop problem-based learning and concept mapping by using a block-based programming model (PBL-CBp model) and to evaluate the appropriateness of the PBL-CBp model. The research will be divided into two parts. The first part will be about learning style development and will study the theories and ideas which relate to problem-based learning, the programming process and the concept mapping and block-based programming. It will synthesise the steps in the problem-based learning method, and the steps in the program process and design the learning steps by using problem-based concept mapping and block-based programming. The second part will consist of an evaluation of the appropriateness of the model. An appropriateness questionnaire for the PBL-CBp model will be created and the PBL-CBp model will be submitted to five experts for improvement.**

After evaluation of the appropriateness of the PBL-CBp model, the experts found that the overall view was that it was 'very good' ($\bar{x}$=4.71, S.D.=0.49), that the input part was also 'very good' ($\bar{x}$=4.58, S.D.=0.55), as was the learning processes ($\bar{x}$=4.85, S.D.=0.40). The evaluation was 'good' ($\bar{x}$=4.30, S.D.=0.48) and the feedback was 'very good' ($\bar{x}$=4.80, S.D.=0.42). The results show that this PBL-CBp model could be used to enhance the programming competency of undergraduate students in computer science.

Keywords **– Problem-based learning, Concept mapping, Block-based programming, The PBL-CBp model**

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1. Introduction

The computer science programme has been on the bachelor degree curriculum in many governmental universities for 30 years, including the Rajamangala University of Technology, the Rajabhat University and other private universities. There are now many experts in computer science due to the rapid development of innovations in technology and such knowledge is important to governmental and private organizations.

Writing a computer program is a necessary skill in computer science. Students learning how to write a computer program will be taught to understand program coding and data structure. They will learn how to analyse and solve problems using specific methods and to recheck the solutions. Then the students will transfer the solutions into programs using computer language and test them for syntax or logic errors to ensure the results are accurate. The final step in this process is maintenance, which depends on user demand and is important to improve or change the program.

When students graduate in computer science, they have a range of employment opportunities including; analysts and designers of ICT systems, systems network or database administrators, software project managers, programmers, website developers, graphic and animation designers and game developers.

Program coding is a useful skill that can be used in many careers. Recently, the demand for programmers has increased. When students learn about computer science, they find writing computer programs difficult. Some give up because they must learn the computer language in English. They also need to understand how programs are used, the structure and meaning of language in program coding, the structure of program coding and learn planning, developing and testing skills and learn how to debug programs. Students do not understand the problems the first time they use coding, and how they learn depends on how they cope with such difficulties.

The teaching of computer science and the development of problem-based and concept mapping learning by using a block-based programming model has not been developed for computer programming proficiency. This research is interested in developing problem-based learning and concept mapping by using a block-based programming model to enhance the programming competency of undergraduate students in computer science (PBL-CBp model). The purpose of this research is to teach program coding to students and help them to understand program coding and apply it to other subjects.

2. Objectives of the Research

1. To develop a PBL-CBp model.
2. To evaluate the appropriateness of the development of a PBL-CBp model.

3. Research Hypothesis

The PBL-CBp model will be evaluated by experts to get a rating of 'very good'.

4. Scope of the Research

4.1 Population and Sample

For the learning model, the population is a group of experts who teach program coding at universities. The sample consists of a group of five experts chosen by purposive sampling. There are three experts in the learning model who graduated with a doctoral degree and have taught at university for at least five years and two experts in program coding who graduated with a doctoral degree and who have taught at university for at least five years.

4.2 Variables

The independent variable is the PBL-CBp model.

The dependent variable is the result of appropriateness of the PBL-CBp model as assessed by experts.

5. Research Instruments

1. The PBL-CBp model.
2. A questionnaire about the appropriateness of the PBL-CBp model.

6. Data Collection

To collect data, the questionnaire about the PBL-CBp model will be issued for evaluation by three experts in developing the learning model and two experts in program coding.

7. Conceptual Framework

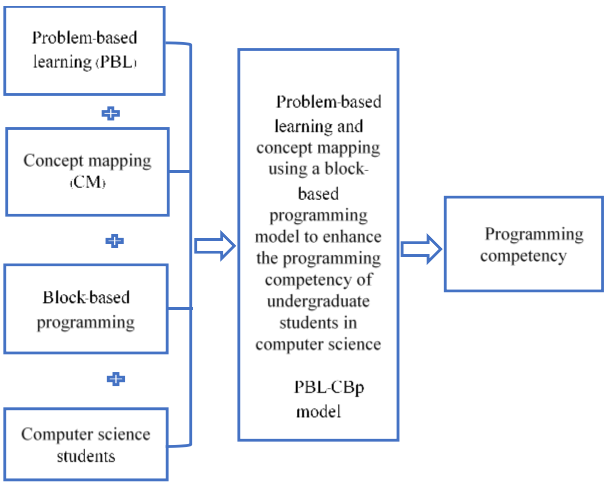

Figure 1. Conceptual Framework

The conceptual framework shown in Fig. 1. consists of the problem-based learning style. This style uses problem-based learning as the stimulus for students who need to solve certain problems then express their ideas in concept mapping. They then write block-based programs (achievement) which helps them to understand the systems. This model will be applied to bachelor degree computer science students. There are ways to evaluate the learning, the first uses the students' scores from their pre and post-program coding achievement taken from the questionnaire that was designed by the researcher.

8. Literature Review

8.1 Problem-based Learning

Problem-based learning is a style of learning taken from constructivist learning theory which says that learning is an active and constructive process whereby students construct new knowledge while solving problems. As a result, they practice many different types of thinking, such as critical thinking, analysis, synthesis, creative thinking and problem solving techniques [1], [2]. This style of learning has been applied by many researchers, for example, [3] who applied PBL to martronics to imitate a surface-drilling vessel. Students gained experience by brainstorming, group working, speaking, writing, independent study and problem solving and expressed their ideas by creating a model and simulation. [4] applied PBL in a laboratory in a technical college. It enhanced the efficiency of the learning process during experiments in electronic engineering in Lvlv Polytechnic National University where students found solutions to problems which is the basis of learning and essential to any future career. [5] applied PBL to teach Java program coding in a laboratory which facilitated students learning coding for the first time. Learning in the Java programming laboratory (JPL) consisted of solving problems using a computer and how to write program language including syntax and semantics. The results from each student at the JPL were automatically recorded and the teacher could check their results and identify any problems. Learning in this way helps students to focus on their ideas and the advice from the results of the JPL tests motivates them.

8.2 Concept Mapping

The idea of concept mapping comes from David Ausubel's theory which said that to learn meaningfully, students must relate new knowledge to what they already know. The new knowledge becomes meaningful when transferred to the background knowledge. Concept mapping is effective in understanding content [5], [6]. It expresses creativity, so it can be applied to the subject of program coding. It is real time concept mapping with peer evaluation. Students must create concept mapping to show their processes when program coding which helps teachers to analyse their misunderstandings and makes it easier for experts to provide them with advice. When students use concept mapping, their achievements are improved [7].

8.3 Block-based Programming

MIT media introduced the concept of block-based programming to develop an interface and create a computer program which used puzzle blocks instead of program coding, structures and complicated instructions [8]. This style of writing programs reduces the necessity for a program language structure because it is developed in an environment which is easier to use, with components such as pictures and buttons. They developed and evaluated it as being equally effective as regular program coding [9]. The Scratch platform has been used in the teaching of computer science because it reduces the need for a written program. Students can create animations and games without the need for codes and without having to learn the syntax of a programming language. Block-based programming helps young students to understand computer science and is easier for teachers without any knowledge of program coding to use.

9. Research Methodology

For research purposes, the research methodology consists of two phases, as follows:

Phase 1: Develop the learning model.

1.1 Study the documents, ideas and related PBL theories, the steps of program coding, concept mapping and block-based programming.

1.2 Synthesise the learning steps using PBL.

1.3 Synthesise the steps of program coding.

1.4 Design the PBL and concept mapping learning steps by using block-based programming.

Phase 2: Evaluate the appropriateness of the learning model.

2.1 Create a questionnaire about the appropriateness of a PBL-CBp model.

2.2 Take a PBL-CBp model to experts for evaluation and advice.

10. Design of the PBL-CBp Model

The design of a PBL-CBp model consists of 3 steps, as follows:

1. Synthesise the steps of the learning processes using PBL.
2. Synthesise the steps of program coding.
3. Synthesise the steps of learning by using PBL with the steps of program coding then integrate them with concept mapping and block-based programming.

10.1 Synthesising the Steps of the Learning Processes Using PBL

Synthesising the steps of the learning processes using PBL has been studied by several researchers, as follows: [10], [11], [12], [13], [14], [15] and [16] See Table 1.

Table 1. Synthesis of the Learning Steps using PBL

Learning Steps using PBL	Wasana Pumee (2012)	Aekkamol Boonyapalanan (2014)	Rusada Chapakea (2015)	Tidarat Kanyamee et al. (2016)	Kamolchat Klom-iam (2017)	Preeyanuch Manujum et al. (2017)	Supreeda Bunjun et al. (2017)
Define the problem	✓	✓		✓	✓	✓	✓
Understand the problem	✓		✓	✓	✓	✓	✓
Identify the problem			✓				
Define the steps of solving the problem	✓						
Analyse the problem			✓				
Identify content		✓	✓				
Continue research	✓	✓	✓	✓	✓	✓	✓
Synthesise knowledge	✓		✓	✓	✓	✓	✓
Conclude and evaluate the answer		✓	✓	✓	✓	✓	✓
Present and evaluate students' work	✓	✓	✓	✓	✓	✓	✓

The Table shows that PBL has six steps; define the problem, understand the problem, continue the research, synthesize knowledge, conclude and evaluate the answer and present and evaluate students' work.

10.2 The Synthesis Steps of Program Coding

The synthesis steps of program coding have been studied by several researchers, including; [17], [18], [19], [20], [21], [22], [23]. See Table 2.

Table 2. Synthesis of Steps for Program Coding.

Steps for Program Coding	Thanyaporn Ban-apai (2012)	Anusak Sang-ubon (2013)	Kaiyasit Apira-thing (2014)	Panapak Piewklieng (2014)	Surasak Karb-ngern (2014)	Darineee Inpaeng (2015)	Chatchada Chuensin (2016)
Analyse problem	✓	✓	✓	✓	✓	✓	✓
Identify user requirements	✓						
Design the system processes	✓						
Check the processes	✓						
Design the program	✓	✓	✓	✓	✓	✓	✓
Coding the program	✓	✓	✓	✓	✓	✓	✓
Test and improve the program	✓	✓	✓	✓	✓	✓	✓
Using the program	✓				✓		
Write the manual for the program		✓	✓	✓		✓	✓
Maintenance of the program	✓	✓					✓

There are five steps for program coding; analyse the problem, design the program, code the program, test and improve the program and write a manual for the program.

10.3 Synthesising the Steps of Learning using PBL with the Steps of Program Coding and Integrating this with Concept Mapping and Block-based Programming

Synthesising the steps of learning using PBL with the steps of program coding and then integrating this with concept mapping and block-based programming has 12 steps, as follows, define the problem, analyse the problem, search for information from resources, synthesise knowledge, write the concept from concept mapping, design the program using block-based programming, code the program using block-based programming, test the program using block-based programming, improve the program using block-based programming, write the manual for the program, present the program, and evaluate students' work.

11. Research Result

11.1 Learning Model

The PBL-CBp Model

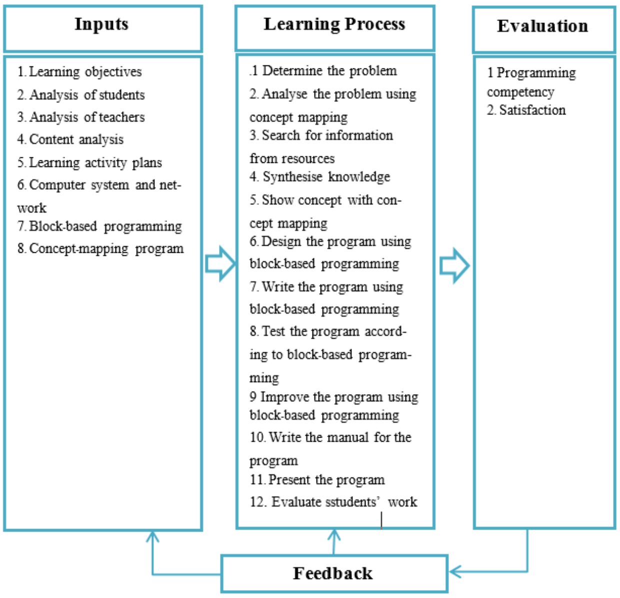

Figure 2. Overview of the PBL-CBp Model.

Figure. 2. shows the PBL-CBp model consists of four elements:

1. Input

The separate parts of the inputs are as follows:

1.1 Learning Objectives

The learning objectives should be determined by analysis of the curriculum content to ensure each unit matches the course description. The objectives should be specific so that learners can accomplish them and teachers can assess them. Teachers should determine the style of teaching and learning and the method of evaluation.

1.2 Analysis of Students

The purpose of analysing the students is to find out their level of intelligence and learning styles. Teachers will then know students' preferences and abilities and adapt their teaching style accordingly. Teachers can use the data to group learners according to their knowledge and ability. They can also design an appropriate style, activity and evaluation so that all students can achieve the learning objectives.

1.3 Analysis of Teachers

The analysis of teachers is carried out to prepare them to use the most effective learning style, activities and processes. Teachers must be experts in PBL, concept mapping and block-based programming.

1.4 Content Analysis

Content analysis determines what curriculum content students need to know. It consists of objective analysis of the subject and relating it to each learning objective. Developing the instruction media is also appropriate at this stage so that students can understand and design their instruments for evaluation.

1.5 Learning Activity Plans

Learning activity plans are the teachers' plans for arranging lessons and activities in the classroom or for preparing to teach in advance. Teachers refer to these plans in every teaching period or hour to teach students and for the development of learning activities. The plans also help students to accomplish their learning objectives.

1.6 Computer System and Network

This learning style is program coding which requires the use of computer systems and networks. It is done online to use and improve block-based programming.

1.7 Block-based Programming

Block-based programming is program coding in blocks which requires the components of hardware and users. Program developers write codes using pictures instead of coded instructions and students can drag and drop blocks to a structure.

1.8 Concept Mapping

The concept mapping program creates a diagram to represent knowledge, and uses conceptual mapping to manage the structure, and then transfers the data. It is an instrument used to manage creative thinking.

2. Learning Processes

The learning processes have 12 parts, as follows:

2.1 Define the Problem

This is the definition of the students' problem or the students determining the problem. It needs to identify problems from a range of situations that the students want to solve. These problems can be applied to the processes and to the writing of the program.

2.2 Analysis of Problems using Concept Mapping

Analysing problems using concept mapping produces the data required to produce the results. Program writers must understand this because if they do not analyse the problem correctly, the result will not be accurate. Concept mapping demonstrates the concept of analysis. Analysing problems by concept mapping has several parts including the purpose of program coding, results, inputs, variables and the processes of the program.

2.3 Searching from the Resources

Students will learn, revise, search for new knowledge, and identify resources. They will have the freedom to search for additional information from other resources according to their proficiency.

2.4 Synthesising the Knowledge

Synthesising knowledge is applying the knowledge from the resources and using this knowledge to check and solve problems. If there is not enough knowledge, the learners will search for more information, from learning activity plans and additional resources and then search again for more information to get the computer data.

2.5 Producing a Flowchart using Concept Mapping

Producing a flowchart using concept mapping helps beginners in coding understand the system and the programs and can be used to check that what it depicts is correct and effective. Producing a flowchart using concept mapping for block-based programming does not require a written process description at every step. Producing the flowchart expresses ideas and shows the relationships between systems in spider charts, organisation charts or flow diagrams.

2.6 Designing the Program using Block-based Programming

Designing the program using block-based programming from analysis to design. The design will determine what kind of block will be used such as a block of control, a variable, an operator or utilities.

2.7 Coding the Program using Block-based Programming

Writing a program using block-based programming will choose the blocks designed to be in order and determine the data such as the numbers of repeats and variables.

2.8 Testing the Program according to Block-based Programming

Testing the program is done either when it is finished or not finished. When students code programs in parts, it is easier to find errors because they are in each part and not in the overall program.

2.9 Improve the Program according to Block-based Programming

Improving the program is necessary if it does not work correctly. To correct the program, programmers need to delete blocks or add more blocks. They must improve and test the program and re-check the result.

2.10 Creating a Manual for the Program

Creating a user manual for the program that describes the overall program and the system of programs, and helps users to use the program correctly.

2.11 Presenting the Program

In this step, the learners present the program they have produced during their learning and searching. They analyse, synthesise and produce a flow-chart, design and code a program as well as correct any errors until they get a complete working program. After that, they create a manual for users and present their work in the classroom and take part in a discussion.

2.12 Evaluating the Students' Work

In this step, the students' work including design, presentation and testing is evaluated.

3. Evaluation

The evaluation has two parts, as follows:

3.1 Programming Competency Evaluation

This evaluation is carried out pre-test and post-test to ascertain whether students have enhanced their programming competency.

3.2 Satisfaction Evaluation

This evaluation uses a questionnaire to evaluate students' satisfaction with the learning processes including inputs, processes and evaluation.

4. Feedback

The feedback has two parts, as follows:

4.1 Evaluation Result of Programming Competency

Programming competency tests a students' knowledge according to the learning objectives. If students are not competent enough in programming, the feedback will be to revise the learning processes.

4.2 Evaluation Result of Satisfaction

Satisfaction is measured from the feedback and is used to improve the learning model such as improving the inputs, the learning processes and the outputs of a system.

11.2 Evaluation of Appropriateness

To evaluate the appropriateness of the PBL-CBp model, the researchers asked five experts to carry out an evaluation. The results are shown in Table 3.

Table 3. The Appropriateness of the PBL-CBp Model in each of the Components.

Description	Result		Rate of appropriateness
	$\bar{x}$	S.D.	
1. Inputs			
1.1 Learning objectives	4.20	0.84	Good
1.2 Analysis of students	4.40	0.55	Good
1.3 Analysis of teachers	4.00	0.00	Good
1.4 Content analysis	4.40	0.55	Good
1.5 Learning activity plan	4.80	0.45	Very good
1.6 Computer system and network	4.80	0.45	Very good
1.7 Block-based programming	5.00	0.00	Very good
1.8 Concept mapping program	5.00	0.00	Very good
Average	**4.58**	**0.55**	**Very good**
2. Learning processes			
2.1 Define problem	5.00	0.00	Very good
2.2 Analysis of problem using concept mapping	5.00	0.00	Very good
2.3 Search from resources	4.40	0.55	Good
2.4 Synthesis of knowledge	5.00	0.00	Very good
2.5 Write the concept from concept mapping	5.00	0.00	Very good
2.6 Design the program using block-based programming	5.00	0.00	Very good
2.7 Coding the program using block-based programming	5.00	0.00	Very good
2.8 Testing the program using block-based programming	5.00	0.00	Very good
2.9 Improve the program using block-based programming	5.00	0.00	Very good
2.10 Create a manual for users	4.60	0.89	Very good
2.11 Present the program	4.80	0.45	Very good
2.12 Evaluate students' work	4.40	0.55	Good
Average	**4.85**	**0.40**	**Very good**
3. Evaluation			
3.1 Programming competency evaluation	4.20	0.45	Good
3.2 Satisfaction evaluation	4.40	0.55	Good
Average	**4.30**	**0.48**	**Good**
4. Feedback			
4.1 Evaluation result of programming competency	4.80	0.45	Very good
4.2 Evaluation result of satisfaction	4.80	0.45	Very good
Average	**4.80**	**0.42**	**Very good**
Overall average	**4.71**	**0.49**	**Very good**

Table 3. shows the evaluation by five experts of the appropriateness of the learning model designed by the researchers. The overall result is 'very good' ($\bar{x}$=4.71, S.D.=0.49). For input, the result is 'very good' ($\bar{x}$=4.58, S.D.=0.55). For the learning process the result is 'very good' ($\bar{x}$=4.85, S.D.=0.40). The result for evaluation is 'good' ($\bar{x}$=4.30, S.D.=0.48) and the result for feedback is 'very good' ($\bar{x}$=4.80, S.D.=0.42). This shows that the PBL-CBp model can be adapted to teaching.

12. Conclusion and Discussion

The PBL-CBp model has four elements: input, learning processes, evaluation, and feedback. The input element has eight parts: learning objectives, analysis of learner, analysis of instructor, content analysis, lesson plan, computer and network system, block-based programming and concept mapping program. The learning process has 12 parts: define the problems, analyse the problems using concept mapping, search for resources, synthesise knowledge, draw a diagram using concept mapping, design a program according to block-based programming, coding the program using block-based programming, test the program using block-based programming, improve the program according to block-based programming, create a manual for the program, present the programme and evaluation of students' work. The evaluation which has two parts: evaluation of programming competency and evaluation of satisfaction. The feedback has two parts: evaluation of the results of programming competency and the evaluation of satisfaction levels.

After evaluation of the appropriateness of the PBL-CBp model, the experts found that the overall view was that it was 'very good' ($\bar{x}$=4.71, S.D.=0.49), that the input part was also 'very good' ($\bar{x}$=4.58, S.D.=0.55), as was the learning processes ($\bar{x}$=4.85, S.D.=0.40). The evaluation was 'good' ($\bar{x}$=4.30, S.D.=0.48) and the feedback was 'very good' ($\bar{x}$=4.80, S.D.=0.42). The results show that this PBL-CBp model could be used to enhance the programming competency of under-graduate students in computer science.

To develop a PBL-CBp model, the researchers studied documents and the work of other researchers then applied their knowledge to analyse and synthesise their model and then considered the evaluations of five experts. The researchers developed this learning model according to the Universal Systems Model (USM) which consists of four main elements. The first element input consists of eight parts: learning objectives, analysis of learners, analysis of teachers, content analysis, learning activity plans, computer systems and networks, block-based programming and concept mapping programme. This relates to the analysis of input by [24] who researched a project based learning model using discussion and lessons based on a social network to enhance the problem solving technique. The researchers separated the inputs into four parts, the analysis of the condition, the analysis of students, content analysis and learning objectives. Teachers analysed the classroom environment and grouped their students accordingly. Each group connected to the internet to use social network media. The teacher assisted the students who needed to learn the basics of Information Communication Technology (ICT). In content analysis, teachers analysed the content for discussion during the learning processes, and compiled the learning objectives. Teachers divided the learning objectives into two parts such as, learning achievement and solving problem technique and learning processes. In the learning processes part, the researchers synthesised the problem-based learning and the steps for writing a program by using concept mapping and block-based programming. It consisted of twelve steps which relates to the research of [16] into problem based and concept mapping to develop students' achievement. Their research found that students' analysis skills and achievement in science increased because problem-based learning helped them to discover and understand problems. As a result, they actively searched for information. The researchers evaluated the proficiency of program coding and students' satisfaction which related to the research of [16]. This research evaluated the students' achievement and asked how satisfied the students were with the problem-based and concept mapping learning model. Moreover, it related to the research of [15] into the development of achievement using problem-based learning and STEM education for critical thinking. They pre-tested and post-tested students' critical thinking skills and evaluated their satisfaction with problem-based and STEM education learning. Finally, the researchers used the result of program coding proficiency and the results of students' satisfaction as inputs or learning processes which relates to the research of [24]. They researched the project-based learning model by using discussion and simplification from social networks to enhance problem-solving skills. The feedback was taken from the input evaluation, during the learning process to improve teaching.

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