The Analysis of Programming Problem Solving Skill of the students in Software Engineering Vocational High Schools

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Abstract

Programming problem solving ability is one of the basic skills of Software Engineering Vocational High School students. As a prospective programmer or software developer, vocational high school students must be able to understand problems, make plans and implement them in computer programs. However, research that tries to explore the level of problem solving ability in programming, especially for vocational high school students is still few or even non-existent. The purposes of this research are 1) to know how good problem-solving skill of vocational high school students, 2) to explore problems of programming teaching and learning especially in the pandemic era, 3) to analyze which problems influenced student's programming problem solving skill according to relevant theory. This research is a mix method research with sequential explanatory model. The result of the study showed that programming problem solving ability is low. From 83 respondents, the average problem-solving score was 33.37 out of 100. Based on the data from questionnaires interviews and learning documents we identify some problems occurred in programming class. By analyzing them with relevant theories, we found several problems in programming class which indicated influencing programming problem solving skill. Those are: lack of motivation and self-confidence, lack of

learning resources, low ICT literation, syntax-based programming learning, and the lack of variety of problem solving being provided.

Keywords

- Problem Solving, Programming, Vocational High School, e-Learning, teaching-learning problems

1. Introduction

The industry's need for programmers is increasing year by year and it will remain a trend in the future (Gurcan and Kose 2017; Scaffidi, et al. 2005; Smith and Ali 2014). This economic aspect is one of the reasons for the inclusion of programming or coding in the curriculum in several countries (Passey 2017; Vinnervik 2022). Another aspects are organizational, community, learning and learner (Passey 2017). In Indonesia, this subject is included in national curriculum of Junior High School, Senior High School, and software engineering vocational high school.

Programming is a subject that involves the ability to design algorithms, write programs, understand syntax, as well as program logic (Rahmat et al. 2012). In the field of computer technology, especially in software engineering, programming is the most important subject for students. This subject lays the foundation for the logic, algorithmic, and problem-solving skills that are essential for later subjects such as web programming, desktop programming, and mobile programming.

Software engineering program is one of the majors in a vocational high school that specifically studies computer programming. This program is growing rapidly along with the increasing industry demand for programmers. However, programming is considered as one of difficult subjects by students (Daly 1999; Jenkins 2002). The reasons why this subject is difficult are the subject itself, students, and teachers (Rahmat et al. 2012). From the subject point of view, programming skills are multilevel skills, from basic to advanced skills, ranging from basic syntax, semantic, structure, and style. Programming is also a multiple skill, such as creating algorithms, translating algorithms into program code, and writing programs with the correct syntax. From the student's perspective, most students get bored quickly if they are not interested in this subject. The way the teacher teaches is also a factor why students are not interested in this subject.

One of the skills that programmers must have is problem solving skills. Programmers must first understand how a human solves a problem, then understand how to translate this "algorithm" into something a computer can do, and finally how to "write" the specific syntax (required by a computer) to get the job done. However, previous studies have shown that many students were lack of problem-solving skills (Lawan et al. 2019; Marques and Marques 2012; Papadopoulos and Tegos 2012; Psycharis and Kallia 2017). This skill is very important for graduates of software engineering vocational high schools to compete in the industry, considering that the absorption of vocational graduates in general is still low in the workforce. In fact, data from the Indonesian Central Statistics Agency (BPS) shows that SMK graduates produce the highest open unemployment among all levels of education (Soelistiyono and Feijuan 2022; Ulfah, et al. 2020).

1.1 Objectives

Because of the importance of problem solving skill for students, in this research, we want to know: 1) how good is problem solving skill of the students, 2) what are the problems in learning problems, 3) which problems are indicated influence student's programming problem solving skill in vocational high school.

2. Literature Review

2.1. Problem Solving in Programming

Problem solving as a summary of cognitive processes that focus on changing from an initial state to a final state where there is no clear solution procedure (Mayer 1990). The solution to the problem and its cause is defined by Funke which includes several things (Funke 2010). Funke stated that one's initial knowledge of the problem is the initial condition, while the operation is a permissible activity that can be carried out to achieve the final state (result) with the help of available instruments. In achieving the goal there are obstacles that must be overcome (such as lack of knowledge or the absence of a clear/direct strategy). The process of overcoming these obstacles can include cognitive, motivational, and emotional aspects. Problem solving has several alternative solutions (solutions).

A problem solving process was proposed by G. Polya in his book entitled "How to solve it" explains in detail how a problem can be solved, which includes 4 stages as follows: a) understanding the problem; b) planning the problem solving; c) implement problem solving (solution) based on the plan; and d) Re-checking or evaluating the results of problem solving that has been done (Polya 2019). Polya's problem-solving step was adopted by Barnes, et al (1997) in programming learning which was named, "How to Program It", which includes 4 stages: understand, design, write (write the program), and review (looking back).

Dale, et al (2003) stated that in making a computer program, one must go through two phases, which are the problem -solving phase and the implementation phase. The problem-solving phase includes analysis and specification, determining a general solution in the form of an algorithm, and verifying whether the algorithm steps have really solved the problem. The implementation phase is writing a program based on the algorithm, testing to check the results, finding errors (debugging), analyzing the causes of errors and fix them. If these two phases have been completed, you can proceed to the maintenance phase which includes the use of the program and modification of the program if there are changes in specifications. These two phases of programming problem solving can be used to measure problem solving skills.

Wicaksono and Korom (2022) summarize the development of an instrument to measure problem solving ability in various subjects. There are two types of tests used, essay and multiple choice, but most of them are essays. However, essay assessment takes longer because it must be done manually. Alternatively, we can use multiple choice tests in order to produce faster response. Chen, et al (2020) showed that multiple-choice problem-solving measurement was able to provide equivalent measurement compare to the open-ended question (essay).

2.2. Factors Affecting Problem Solving Ability

Park and Jang (2010) summarize the factors that influence problem solving ability in online learning environment as follows.

1) Factors from Students, including:
   a) Cognitive Ability
      One of the cognitive abilities in finding solutions is the ability to break down the subject matter into instructional goals. Another ability is task analysis, which generates a hierarchy of sub-tasks in the problem-solving task. Cognitive ability also includes how to coordinate and control cognitive components such as encoding, inferring, and applying information to problem solving.
   b) Metacognitive ability
      Metacognitive ability is the ability to plan, monitor, and evaluate activities related to problem solving.
   c) Self Confidence
      Self-confidence is the main source of successful problem solving (Foshay and Kirkley 2003). They concluded that "the belief I can", is important for learning to be able to solve problems. Likewise, Hepner and Beker (1997) stated that when students face a difficult or unstructured problem, students will find it very difficult to find a solution if it is not accompanied by confidence in their abilities.
   d) ICT Literacy
      Students' ICT literacy can contribute to improve problem solving skills in online learning environments (Smeets 2005).
2) Learning environment.
   The learning environment acts as a support system that provides the necessary resources and tools to guide problem solving. Through problem solving, students can construct their own knowledge based on their experience and gain more problem-solving skills. Learners need a learning environment to be actively involved in knowledge construction.
3) The role of the teacher/tutor
   The role of the teacher/tutor in problem solving is elaborating, directing the learning process, integrating knowledge and stimulating individual interaction and accountability.
4) Interaction among students
   Park and Jang emphasize that students interact with one another by providing various scaffoldings during problem solving in an online learning environment. Students can learn constructively through the interaction of fellow students by being guided to reflect on the problem-solving process and by asking other students to provide an assistance and feedback.
5) Characteristics of the Problem

Real world problems are usually more complex and unstructured. New students will have difficulty in solving unstructured problems. Therefore, students can achieve good thinking skills by increasing the practice of solving problems gradually from easy to difficult.

These factors will be used as a guide to identify problems that affect problem solving skills in programming learning.

3. Methods

This study is sequential explanatory mixed methods study. This design will be implemented in two distinct phases. The first phase involves collecting and analyzing quantitative data. Base on a need to further understanding the quantitative results, researcher implements a second qualitative phase that is designed to help explain the initial quantitative results (Creswell and Planoclark 2011).

First Phase

In this phase we collected data of problem solving skill using a test and data of programming learning problem using a questionnaire. Based on the two phases of programming (Dale et al. 2003), we formulate some indicators of programming problem solving skill as in Table 1.

Table 1. Indicators of programming problem solving skill test

Component	Aspect	Indicator
Ability of analyzing and determining specification of program	Understand the problem	Determine the correct input and output of a problem Determine input and output component of the problem
	Determine the solution in algorithmic form	Determine the correct algorithm of a problem
	Evaluate the algorithm	Trace an algorithm of the solution of a problem Evaluate an algorithm of the solution of a problem
Ability of implementing algorithm into program	Writing program (code) based on an algorithm	Determine correct variable and its data type Writing program (code) based on an algorithm
	Testing program	Trace the output of a given program Evaluate syntax error of a program Evaluate logical error of a program

From the indicators in Table 1, 20 multiple choice questions are arranged according to the programming language used in each school, which are C and C++.

Quantitative data is also collected using questionnaires to find out some problems during programming learning. Aspects of programming learning problems in this questionnaire include: 1) Student's Perception of Learning Programming, 2) Availability of Learning Resources for Basic Programming Materials, 3) Support for Students with Learning Difficulties, 4) Application of Problem Based Learning, 5) Students' initial knowledge of problem solving, and 6) Student needs for a new learning system that supports the availability of problem-solving-based materials. The questionnaire consists of 17 statements with agree/disagree scale: strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), and strongly agree (5).

Second Phase

In this phase, a qualitative study was conducted to confirm the findings in the previous phase by conducting in-depth interviews with teachers and analyzing documents such as lesson plans and programming learning handouts. The findings of the learning problems are then compared with the theory regarding the factors of problem solving ability to answer the last question of the research.

The steps of research are shown in Figure 1.

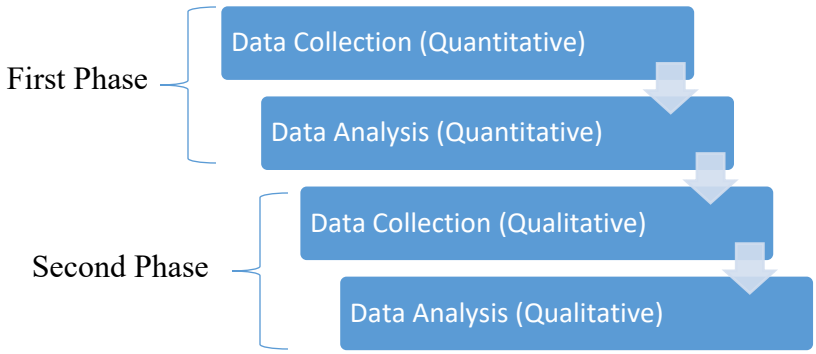

Figure 1. Steps of the research

4. Data Collection

The research was conducted by involving two vocational high schools of software engineering in Surakarta, including 2 teachers and 83 students in basic programming classes. These 2 samples were selected from 3 vocational high schools with software expertise in Surakarta Indonesia.

5. Results and Discussion

5.1. Data of Problem Solving Test

The result of test on Programming Problem Solving is shown in Table 2.

Table 2. Descriptive Statistics of Programming Problem Solving Skill

Mean	Minimum	Maximum	Deviation Standard
33.37	10	100	15.59

From the table above, problem solving ability is quite low with an average of 33.37 out of 100. Details on the achievements of each aspect are displayed on Figure 2. The lowest score in problem solving ability is program writing ability, while the highest ability is algorithm verification ability.

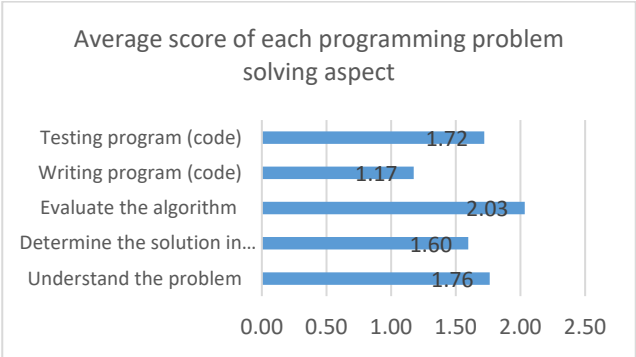

Figure 2. The achievement of each aspect in programming problem solving test result

5.2. Questionnaire Data of Programming Learning Problems

From the Table 3, we found some results as follows. There were 53.1% of the students stated difficulties in learning basic programming. Although the modules have been provided by teacher, 84.8% of students think that learning resources are not sufficient enough and they still need additional learning resources. In addition, students' confidence in solving problems is low. Only 36.6% of the students expressed confidence in solving problems. Some students also

do not understand the processes of problem solving. There were 45.5% of the students directly typed the code on the computer and 54.3% carefully planned the problem-solving strategy before typing the program code.

By this result we found fact that about half of the students had difficulties in learning programming. They faced some problems in programming learning such as the lack of learning resources, low confidence in problem solving, and ignorance of problem-solving process.

Table 3. Result of the questionnaire in programming learning problems

Statement	Strongly Disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly Agree (%)
1. I think basic programming is a difficult subject	3.6	19.3%	44.6%	26.5%	6.0%
2. I like basic programming subjects	0.0%	7.5%	28.8%	50.0%	13.8%
3. Basic programming subjects are less important than web programming or other programming	37.5%	37.5%	21.3%	3.8%	0.0%
4. I have difficulty in learning basic programming	1.2%	9.9%	35.8%	30.9%	22.2%
5. Learning resources used in learning basic programming vary (not only modules from the teacher)	2.5%	4.9%	23.5%	32.1%	37.0%
6. The module used by the teacher is easy to understand	1.3%	15.0%	43.8%	31.3%	8.8%
7. I need additional learning resources other than the module provided by the teacher	0.0%	2.5%	12.7%	29.1%	55.7%
8. If I have difficulty in learning basic programming, teachers or friends often help me	0.0%	2.5%	29.1%	29.1%	39.2%
9. I'm shy/embarrassed to ask my teacher or friends if I have difficulty learning basic programming	26.8%	28.0%	26.8%	13.4%	4.9%
10. The teacher provides directions or additional special lessons for students who have difficulty following basic programming lessons	1.3%	3.8%	32.5%	40.0%	22.5%
11. The teacher conveys basic programming material by using real examples of application in daily life (contextual)	2.5%	7.4%	32.1%	37.0%	21.0%
12. During learning basic programming, the teacher often gives problems to be solved by programming	0.0%	3.8%	31.3%	43.8%	21.3%
13. I am not confident if I get a programming project to solve a problem	13.4%	23.2%	37.8%	13.4%	12.2%
14. When I solve the problem, I immediately type the code on the computer	2.5%	20.3%	31.6%	27.8%	17.7%
15. When solving a problem, I carefully plan the solution strategy before typing the code	2.5%	4.9%	38.3%	35.8%	18.5%
16. I have trouble finding and fixing errors in the program that I finished making	2.5%	19.8%	38.3%	22.2%	17.3%
17. When learning basic programming I have problems with the device I have	21.0%	21.0%	29.6%	16.0%	12.3%
18. I feel there needs to be a complete tutorial system for basic programming learning and problem solving exercises	0.0%	2.5%	12.5%	18.8%	66.3%

5.3 Interview Result

After collecting quantitative data of problem solving skill and learning programming problem, we continue with qualitative data collection using interview to confirm and explain the findings in the previous phase. We made

interviews with two teachers and analyzing their teaching documents such as lesson plans and programming learning handouts. These are the result of the interviews.

Teacher 1:

Teacher said that some students had difficulty in solving problems. The teacher stated that only 50% of students could work on it and put it in the form of a program. There were several problems faced by students in learning basic programming. One of them is the lack of motivation in learning programming. Many students do not realize the importance of learning basic programming as a basic skill for software developer. They see basic programming with text-based views (command line instruction) as unattractive and less applicable. Therefore, during learning the teacher always encourages student motivation and provides examples of programming implementation in daily life. The teacher also said learning resources for basic programming are still limited, especially for vocational high school students. Teachers found it difficult to find programming textbooks that are coherent and structured to be used in learning. As a result, teachers use English-language online books and online tutorials from the internet. Because of this language factor, some students have difficulty in learning it. Another problem in learning programming is the lack facilities owned by students. Not all students have a computer at home, but they still have a cellphone as a substitute, even though its abilities are limited. With such obstacles, some students have difficulty in learning programming so they need further assistance from the teacher. However, teachers find it difficult to provide quick feedback and assistance according to the achievements of each student. We also found some wrong perception of problem-based learning of the teacher. He thinks giving problems to students who are just learning programming is not appropriate. His reason is that if the child is not motivated, giving problems will not work. In fact, many studies show that the application of problem based learning can increase student motivation. Teachers also do not really understand how problem-based learning is carried out. He assumes that problem-based learning is done simply by giving some assignments

Teacher 2:

The teacher said that the main problem of learning programming is that not all students have computers. They have cellphone which can do programming, but it is limited. Students are unwilling to read the material, they still fully depend on the teacher, and they are unable to identify errors. Students are afraid to give a try during practice. Some students who enter software engineering class did not make their first choice in school registration, so that they are less motivated. Learning resources are limited to modules provided by the teacher and video tutorials via YouTube. According to the teacher, only 60% of the students can solve problems using programming. For students who do not pass the exam, the teacher only provides the opportunity to complete assignments, without any remedial teaching. The reason is that person-to-person assistance is rather difficult to do. Programming lessons are carried out with more emphasis on syntax, changing from one syntax to another syntax, there are no problems or projects to be completed.

5.4. Document Analysis Result

From the first school, the documents analyzed were a complete lesson plan, including learning steps, modules, evaluation sheets and job sheets. The teacher uses a scientific approach as a learning approach, but there are no problems raised contextually. Likewise, the module is still syntactic, without any examples of problems related to the topics discussed, for example determining the variables and data types of a problem case. Evaluation only measure 2nd level of cognitive domain (understand).

From the second school, the only documents analyzed were modules and worksheets. From these documents, we know that the subject material is presented still in syntactic form, rewriting the code given by the teacher, without any problems being analyzed and resolved.

5.5. Discussion

Based on the results of data collection, there are several problems faced by students and teachers in learning programming, which are:

1) lack of appropriate learning resources,
2) low student motivation and self-confidence
3) lack of facilities, especially laptops or computers to practice programming at home
4) lack of feedback and direction for students who has difficulty in learning,
5) lack of students' understanding of the problem solving steps in programming, where some students directly type program code without make any plan

6) lack of learning experience in solving problems using programming. It can be seen from the modules, job sheets, and lesson plans, which are only syntax-based with no problems to be solved.
7) the wrong perception of problem-based learning of the teacher

As explained earlier, Park and Jang (2010) stated that the factors that influence problem solving abilities are divided into 5: from the students themselves, the learning environment, the role of teachers and tutors, the interaction of fellow students, and the characteristics of the problem.

Factors that come from students include cognitive, metacognitive, self-confidence and ICT literacy. From the results of document analysis, learning plan documents are not settled in improving cognitive and metacognitive abilities. Learning plan still emphasizes at cognitive skills levels 2-3 (C2, C3), which are remembering and applying. We need some efforts to improve students' high order thinking skill, which are reflected in the definition of goals, activity steps, and evaluation. In this case problem-based learning can be applied. Problem-based learning encourages students to be able to think analytically (C4) in identifying problems and formulating solutions to evaluating solutions (C5). Based on previous research, problem-based learning also can improve motivation (Nuutila, Törmä, and Malmi 2005) and enhance the quality of students' learning and problem solving (Looi and Seyal 2014). On the other hand, low self-confidence and ICT literacy skills were also identified as the cause of low problem-solving abilities. The lack of facilities causes some students afraid to try coding.

The next factor that affects problem solving ability is the learning environment, the role of teachers and tutors, interactions among students, and the characteristics of the problem. Related to these factors, we can identify learning problems affecting problem solving skill. The learning environment acts as a support system that provides the necessary resources and tools to guide problem solving. One of the problems is the lack of appropriate learning resources in suitable language which also support problem solving skills. Modules are still in syntax-based rather than problem-based. The environment also has not accommodated for mentoring the students who has difficulty in learning. Based on the document analysis, interaction between students already exists, reflected in the designed learning strategies. The teacher involves students in group work. However, the existing documents do not show any variations of problems to be solved. So that students are not familiar with various kinds of problems and they will have difficulty in solving new problems.

6. CONCLUSION

The result of the study showed that programming problem solving ability is low. From 83 respondents, the average problem-solving score was 33.37 out of 100. Based on the data from questionnaires interviews and learning documents we identify some problems occurred in programming class, which are: lack of appropriate learning resources, low student motivation and self-confidence, lack of facilities, especially laptops or computers to practice programming at home, ack of feedback and direction for students who has difficulty in learning, lack of students' understanding of the problem solving steps in programming, where some students directly type program code without make any plan, lack of learning experience in solving problems using programming, and the wrong perception of problem-based learning of the teacher. By analyzing them with relevant theories, we found several problems in programming class which indicated influencing programming problem solving skill, which are: lack of motivation and self-confidence, lack of learning resources, low ICT literation, programming learning which is still based on syntax only, and the lack of variety of problems to be solve in learning programming. The solution that can be offered to overcome this problem is to apply appropriate learning models such as problem-based learning. Programming learning is not only based on syntax but also provides a lot of experience for students to apply it to various problems. However, learning must also be interesting and fun so that students are motivated and engaged during learning. Further research as an effort to improve problem solving skills in programming is very much needed using appropriate learning strategies.

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