Revisiting the roles of educational robotics in improving learners' computational thinking skills and their positive behaviour

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Abstract. This paper investigates the relationship between the use of robotics in learning towards self-efficacy and computational thinking skills. This paper also examines whether there is a relationship between computational thinking skills and self-efficacy. This paper employed a systematic literature review method by examining forty articles drawn from 'computational thinking', 'self-efficacy' and 'educational robotics' keywords in the literature. The majority of research indicates that the use of robotics in learning facilitates the development of computational thinking skills as well as learners' self-efficacy. The paper advocates that future research should examine the extent of computational thinking skills and self-efficacy influence on student behavior.

1. Introduction

Self-efficacy is closely related to students' confidence and optimism about their ability to achieve the expected results [1]. Self-efficacy can guide students' feelings, thoughts, motivation, and behavior. Directly proportional to achievement, if the student's self-efficacy is good, it will produce better achievements. In addition, self-efficacy is one of the factors that contribute to student perseverance. Those who have high self-efficacy, have more courage and determination to start new tasks and explore them. Self-efficacy is important, because those who have low self-efficacy tend to have difficulty starting something new. This is because their confidence to succeed is low and there is a lack of reason to start a new task [2]. One skill that can increase self-confidence is computational thinking (CT) [3][4][5].

CT is a basic skill that students need to learn in all fields of expertise [3]. CT is a concern because this skill is in the spotlight in the world of education and the world of work. CT equips students to solve complex problems [3][6] and able to translate the process of solving these problems into various other problems [6]. At present CT has been widespread among students and practitioners [7]. For that reason many researchers want to stimulate CT skills, one way is to use and utilize robotics [8][9].

The use of robotics itself in learning has become increasingly common and has an impact on student learning [9]. Students become more interested, feel happy and show enthusiasm when utilizing robotics in learning [10][11][12]. Learning by utilizing robotics is considered fun because it provides a hands-on learning experience [11]. Viewed from a learning point of view, robotics is a good choice because it is attractive to students [12].
Many researches related to robotics in the development of learning need to be explored further to find out where the next research will be. The literature review method is used to examine the relationship between computational thinking, self-efficacy and the use of robotics in learning. This paper aims to analyze the findings of previous researchers in the last ten years to find out robotics influence on computational thinking and self-efficacy.

2. Research Method

To create a new document, simply store the template in a convenient location and double-click it. In this article, the systematic literature review method used is a guide from Okoli and Schabram [13]. Guidelines for carrying out systematic literature review steps are divided into several stages.

Step 1. Plan.
- Determining Objectives of Literature Review
- Determining Standards and Rules

Step 2. Selection.
- Search for Literature
- Literature filtering that will be used

Step 3. Extraction.
- Unused Literature Filtering
- Information extraction

Step 4. Execution.
- Analyze findings
- Write a Review

2.1. Planning

The purpose of this paper is to find out whether the use of robotics in learning influences self-efficacy and CT ability. Next, to check whether there is a correlation between self-efficacy and CT ability. In this planning process, the determination of objectives and standard rules are used. The predetermined goal was the use of robotics to influence CT skills and self-efficacy. Although research related to the use of robotics on CT skills and self-efficacy is fairly new, it is hoped that the number of articles discussing this theme will be found and will increase in recent years. Therefore, the researcher defined four criteria articles which included the research that would be carried out:

- (IC1) Research must be related to education which has an influence on CT skills or self-efficacy
- (IC2) Research must be related to the use of robotics in the world of education which has an effect on self-efficacy or CT skill

2.2. Selection

In this selection process, there are two main activities that are carried out, determining keywords and then selecting articles to be used as literature review material by using a filter process. There are 3 keywords used to conduct the selection process, self-efficacy, computational thinking, and robotics. After the keyword determination process is complete, the next step is the article filter process. This article filter process is used in article databases or journals. For the article database in this study, researchers used two main sources of article database, Scopus and Science Direct. Often in the process of searching for articles when using only one keyword, the results are too general and often there is no connection with the criteria for the article that has been determined. Therefore the way to narrow the search results is by combining the specified keywords. The structure of keyword writing, the word "robotics" is placed at the beginning of the keyword to ensure that the article found has the main topic of robotics as well as in the title, abstract as well as keywords containing the words robotics. The final keywords used in the search database are as follows:
((abstract:robotic* OR document_title:robotic* OR keyword:robotic*) AND ("computational thinking" OR "self-efficacy" OR "self efficacy"))

Where the symbol * means "any word with a given prefix". The two quotation marks are used so that the results of the articles found have the same words as the keywords given. These two quotation marks are often used when the given keyword consists of two words or more. After the results found the boundaries of the next article that is used is in the discussion of articles in the context of education. Whether it's basic education, secondary education, or higher education

2.3. Extraction
The reviewed papers fall under several criteria. The criteria of the paper are those that deal with self-efficacy in the world of education, computational thinking in the world of education, robotics in the world of education and the influence of using robotics on self-efficacy or computational thinking. In figure 1, the number of papers is based on the topic. After review, a matrix is made which contains the title, date of publication, keywords, methods, and insight. This matrix is made to simplify the data extraction process from the paper reviewed.

The sorting process is carried out with the aim of selecting which articles will be used as material for a systematic literature review. This sorting process is carried out on articles that have been obtained after the selection process. In this sorting process, the researcher looks at the context of the article to determine its inclusion in the review. Articles closely related to self-efficacy and/or computational thinking and robotics then related to education will be included in the review. The level of education was exclusive to all levels of education. Articles with low to no relevance to education, will be excluded.

Table 2 depicts the databases and the number of papers included in the analysis. Then the information extraction process is used matrix. The matrix in this context is a set of article data which are prepared in the form of rows and columns whose contents are determined for the researcher in accordance with the purpose of the article to be made. The matrix made contains items, the title of the article, the context of the research article, the method used, the insights and findings obtained and the development for further research. The matrix is made to facilitate the process of combining information when it enters the processing phase.

| Database    | IC1 | IC2 | Total |
|-------------|-----|-----|-------|
| Scopus      | 8   | 15  | 23    |
| ScienceDirect | 1   | 1   | 2     |
| Springer    | 2   | -   | 2     |
| Other       | 6   | 3   | 9     |
| **Total**   | 17  | 19  | 36    |

From the analysis that has been made, the results of the article obtained 17 articles related to the discussion of CT skills or self-efficacy. Then the next 19 articles were found related to the discussion of robotics which had an influence on self-efficacy or CT skills. For articles that have slices with all three keywords that have been determined, there are two articles, the slices of these three keywords are articles that have topics related to robotics that have an influence on CT skills and self-efficacy. For the distribution graph the articles obtained from the article database can be seen in Figure 1.
The article used in the literature review process uses articles that have the age of 10 years since publishing. Exceptions are given in articles that contain direct understanding originating from the originator or inventor of the terms used in this study. As in the case of the context of the notion of self-efficacy originating from Bandura in 1997. The matrix made contains articles, the title of the article, the context of the research article, the method used, the insights and findings obtained and the development for further research. The matrix is made to facilitate the process of combining information when it enters the processing phase.

2.4. Execution
Next to bringing together data from the matrix that has been made, here we focus on the use of robotics, which has a positive effect on self-efficacy and CT skills. As well as the interrelationship between CT skills and self-efficacy. Literature writing and merging of information carried out in this process. The matrix is translated into data. A harmonious result between the findings of the article that has been reviewed and the intended purpose will appear based on the translation of the matrix. The results are outlined in the form of articles while considering the quality of information that has been adjusted to the main purpose.

3. Discussion
Self-efficacy is confident in the ability of other individuals to organize and carry out the actions needed to achieve certain targets [14]. The most powerful component of self-efficacy according to Bandura 1986 is "enactive experience" and "vicarious experience". By successfully doing something directly will increase the level of self-efficacy and the second is when seeing other people successfully reach the target, individuals will have the understanding to be able to do the same thing so as to increase self-efficacy. From the components described in Bandura 1986, experience has the effect of being able to increase self-efficacy. Increased self-efficacy is required to be directly related to practice in order to gain experience [15].

On the measurement of self-efficacy, results cannot be generalized. The measurement is limited with explanatory and predictive value because of the category of self-efficacy in a variety of different mastery [14]. In this paper, self-efficacy is specifically devoted to the ability of robotics practicum education. In the discussion, section will discuss the relationship between the application of hands-on learning and the improvement of student self-efficacy.
The following in table 2 are aspects that form indicators of self-efficacy so that changes in self-efficacy that occur either directly or not be measured. Indicators are categorized into three aspects including level, strength, and generality [14].

Table 2. Self Efficacy Indicators

| Aspects   | Indicators                                                                 |
|-----------|-----------------------------------------------------------------------------|
| Level     | 1. Confidence in the need to take the necessary action                      |
|           | 2. Confidence in the ability possessed to overcome obstacles in the level of difficulty of the task. |
|           | 3. Having a positive view of the work being done.                           |
| Strength  | 1. Able to respond to various situations with a positive attitude.          |
|           | 2. Using life experience as a step to achieving success.                   |
|           | 3. Shows the attitude of self-confidence in the entire learning process.   |
| Generality| 1. Having strong self-confidence towards self-potential in completing tasks |
|           | 2. Having a fighting spirit and not easily giving up when facing obstacles when completing a task. |
|           | 3. Have a commitment to completing academic tasks well.                    |

As explained, self-efficacy is closely related to self-confidence. One crucial skill that prioritizes confidence in its development is Computational Thinking (CT). In 2016 the International Society for Technology in Education (ISTE) included CT as one of the seven standards for students [16]. Some attitudes that are essential dimensions of CT are confident in dealing with complexity; perseverance in working with severe problems; the ability to handle ambiguity, the ability to handle open issues, set aside differences to achieve common goals; knowing someone's weaknesses and shortcomings when working with others [5].

CT is defined as an analytical thought [17], a problem-solving skill through concepts and techniques related to computer science [18][16]. When faced with complex problems, the CT method makes it possible to formulate or associate seemingly tricky issues with a problem that we know how to solve it [19]. Because CT is related to an individual's ability to use everyday technology, CT is an important skill to succeed in society [16]. And for students, they not only become tool users but as tool makers [5]. In essence, CT is thinking like a computer scientist when faced with a problem [20]. The basic components of computational thinking have many definitions among researchers. The details of each CT skill process can be seen in table 3.

Table 3. CT Process and Source

| CT Process                                                                 | Source                        |
|---------------------------------------------------------------------------|-------------------------------|
| Abstraction, Algorithms, Automation, Problem Decomposition, Parallelization, Simulation [5] | Barr & Stephenson (2011)     |
| Abstraction, Automation, Analysis, Abstraction [21]                       | Lee et al. (2011)             |
| Abstraction, Algorithmic Thinking, Decomposition, Evaluation, Generalization [22] | Selby & Woollard (2013)      |
| Abstraction, Algorithms, Decomposition, Debugging, Generalization [23]    | Angeli et al. (2016)          |
| Abstraction, Algorithms, Automation / Pattern Recognition, Problem Decomposition [17] | Wing (2006, 2008)            |
Although the exact components may be different, the important concepts expressed by researchers are mostly uniform in all fields. Computational thinking ability is basically a set of skills needed to transform complex, messy, partially defined real-world problems into forms that can be handled by mindless computers without further assistance from humans [22]. CT process skills generally contain abstraction, algorithm, automation, and problem decomposition. Detailed explanation of each CT process can be seen in table 4 [22].

| CT Process          | Explanation                                                                 |
|---------------------|-----------------------------------------------------------------------------|
| Abstraction         | Make problems easier to understand and simpler by reducing the details and the number of unnecessary variables |
| Algorithm           | The process of building a schema of regular steps that can be followed to provide solutions |
| Automation          | Look for or find patterns/similarities between problems                     |
| Problem Decomposition | Disassemble the problem and break it down into smaller and more understandable parts. |

There is no harm in improving self-efficacy and CT skills, especially as a student who is required to continue learning. Previous literature stipulates that self-efficacy has an important role in the effective use of technology [24]. Self-efficacy can also make students more confident; students become more convinced that they can learn skills and knowledge more efficiently [25]. The higher the self-efficacy, the higher the level of performance to be achieved, the level of goals and the level of effort will also increase [26].

The next issue is whether there are tools to increase CT skills and self-efficacy. From the literature review that has been done, learning by utilizing robotics can be used as a solution. Robotics can be used as a tool that provides a bridge for students to engage and develop CT skills [8]. Learning using robotics is being widely introduced in schools as an innovative learning environment, improving and building high-level thinking skills, and helping students to solve complex problems. Learning by using robots is very promising because it is able to provide instant feedback during problem-solving situations [27]. One of the factors that can improve self-efficacy is through solving problems by focusing on problem-solving abilities [26]. Whereas CT relates to the ability to handle problems [5]. The following are the results of the analysis of the review literature related to robotics on self-efficacy and CT ability:

3.1. Robotic Positive Impact on Self-efficacy

Robotics can foster a feeling of interest in students who are not motivated by conventional learning in the class [28][29]. Students become more competent and confident in problem-solving, abstract thinking, leadership, and team collaboration using robotics [30][31]. The results of the analysis show that students who use robotics have a positive relationship with self-efficacy [32].

| Article                | Context                  | Result                                                                             |
|------------------------|--------------------------|------------------------------------------------------------------------------------|
| Master et al. [33]     | Elementary School Student| The results show that the use of robotics has a positive impact on self-efficacy    |
| Kaloti-Hallak et al.   | Middle School Student    | Robotics has a positive effect on self-efficacy                                    |
| White [30]             | Middle and High School   | As a result, students enhanced their self-efficacies through robotics               |
| Leonard et al. [35]    | High School Teacher      | The result revealed that self-efficacy increased after using robotics              |
Aristawati et al. [36] Undergraduate Students  Students show changes in self-efficacy throughout the treatment.
Weese et al. [37] 5th-9th grade students  Students get a strong improvement in self-efficacy

It can be concluded that the use of robotics has a positive effect on self-efficacy as shown in table 5. Not only do students get positive outcomes related to self-efficacy, teachers also get a positive impact on self-efficacy when applying to learn using robotics.

3.2. Robotic Positive Impact on Computational Thinking
Studies show that the use of robotics in learning also applies core concepts of CT skills [8]. The researchers also began to explore the potential of educational robotic to begin to introduce and develop CT skills [21].

| Article                        | Context                          | Result                                                      |
|--------------------------------|----------------------------------|-------------------------------------------------------------|
| Grover and Pea [20]            | Younger children 4-6 years old   | Having a positive outcome, it is said that children become aware of engineering and technology and build their CT skills. |
| Grover [38]                    | Junior and High School student   | Robotics has a positive impact on the development of CT skills. |
| Penmercha [39]                 | Undergraduate Students           | The results showed that robotics fulfilled their purpose as a medium for combining CT practice. |
| Eguchi [40]                    | Student at Robotic Competition   | The effects of robotics competitions on student CT and problem-solving skills have a very far-reaching positive impact. |
| Aristawati et al. [36]         | Undergraduate Students           | Student demonstrated varied computational thinking skills.  |
| Weese et al. [37]              | 5th-9th grade students           | Students get a great improvement in CT concept.             |

Overall, as shown in Table 6, the use of robotics has a positive impact on CT skills. Another issue is how the CT can be introduced into the classroom and at what age or grade level of children ready to be added to advanced concepts such as abstraction, automation, decomposition, etc. and how to teach CT skills progressively [21].

4. Conclusion
Of the 40 papers reviewed, it can be found that self-efficacy and CT skills have a positive impact on student behavior. The use of robotics in learning can support the development of self-efficacy and CT skills. The use of robotics provides direct feedback from the problem being solved, in which problem-solving skills are needed in order to improve self-efficacy. While CT skills themselves are the ability to handle problems. For a paper that discusses the relationship between self-efficacy and CT, it is still not very much found, but some papers mention that CT-based learning has an impact on self-efficacy. In the future, it is necessary to do research on the relationship between CT skills and self-efficacy, especially in education using robotics to find out whether learning using robotics can improve CT skills and have a positive effect on self-efficacy.
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