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# A Meta-Analysis of the Utilization of Computer Technology in Enhancing Computational Thinking Skills: Direction for Mathematics Learning

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The aim of this research is to summarize and observe how interventions affect students' computational thinking (CT) skills through computer technology. Some common factors predicted to cause students' heterogeneous CT skills would also be examined. A meta-analysis was chosen to conduct this study. Finding and selecting the relevant literature resulted in 43 documents published in the period of 2011 – 2021 which involved 5.088 samples. The formula of Hedges' g was used to measure the effect size. The Z test and the Q Cochrane test were also used to analyze the data. The results of this study revealed that the interventions involving computer technology on students' CT skills had modest positive effect in which computer technology interventions significantly enhanced students' CT skills. It indicates that the learning process utilizing computer technology is effective to enhance students' CT skills. Furthermore, educational level, geographical location, group size of intervention, learning tool, and subject did not moderate students' heterogeneous CT skills. It means that the level of students' CT skills intervened by using computer technology is not affected by the factors. To improve students' CT skills, this study suggests teachers to utilize computer technology into their mathematics teaching-learning process. Specifically, this study suggests teachers to utilize computer technology in implementing mathematics learning process.

Keywords: computational thinking, computer technology, intervention, mathematics learning, meta-analysis

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## INTRODUCTION

Computational thinking (CT) is assumed as a key skill to adjust in 21st century because it helps solve various problems in the life efficiently (Guggemos, 2021; Haseski et al., 2018; Tabesh, 2017; Yadav et al., 2011). In addition, the existence of CT enables individual to make systematic and active decisions using information and communication technology (Haseski et al., 2018). Operationally, Computer Sience Teachers Association (CSTA) and International Society for Technology Education (ISTE) (2011) defined CT as a problem-solving process comprising some criteria such as (1) formulating problems using other tools and computer to solve it, (2) analyzing and organizing the data logically, (3) representing the data by abstracting such as model and simulation, (4) automating the solution by algorithm thinking, (5) analyzing, identifying, and applying the solution to get maximum combination of steps, and (6) transferring and generalizing the problem-solving process to various problems in which the criteria become characteristics that have to be required by students in 21st century. This indicates that CT is one of the important 21st century skills. Therefore, Hunsaker (2020) recommended that students' CT have to be developed and enhanced in every education level by elaborating it in teaching and learning.

CT-based learning can provide some benefits for students economically and academically (Hunsaker, 2020). CT is required in many professions such as scientist and technician (Li et al., 2020). In addition, Yadav et al. (2017) reported that CT can enhance students' motivation, self-efficacy, problem-solving skills, communication skills, and STEM performance. As a consequence, Tabesh (2017) argued that pedagogical contents officially designed in the curriculum have to involve CT. In particular, CT has the closest relationship with mathematics in which a lot of studies regarding the development of CT in mathematics learning have been widely conducted. Barcelos and Silveira (2012) revealed that some existing characters in CT can be useful for facilitating students to contextualize mathematical contents. For example, pattern matching content has the close relationship with mathematical reasoning and numerical and logical sequence that are identic with algorithm development. In addition, mathematics learning in primary school involving CT can help abstracting development skills, so it enhances mathematical understanding and mathematics academic achievement (Chaabi et al., 2019; Lewis & Shah, 2012). Also, some studies reported that CT helps enhance mathematical critical thinking and problem-solving skills (Grover et al., 2015; Maharani et al., 2019). The reports show that CT skills have to be enhanced for students in learning process particularly in mathematics learning.

The enhancement of CT in each education level utilizes computer technology elaborated with learning curriculum in which the implementation of learning approach or model uses computer supported by some learning media such as scratch, website, robot, computer software, and computer games (Park & Lee, 2015; Peel et al., 2015; Figueiredo, 2017; Valovičová et al., 2020). The utilization of computer technology in robotics programming curriculum is carried out to develop CT skills by implementing coding-based learning (Jeon & Song, 2019; Pérez-Marín et al., 2018; Relkin et al., 2021). The use of scratch in programming education such as computer programming and robotic programming is conducted to enhance CT skills (Constantinou & Ioannou, 2018; Esteve-Mon et al., 2019; Pellas & Vosinakis, 2018; Rodríguez-Martínez et al., 2020; Zha et al., 2021). Particularly, website and computer software are also employed to develop CT skills in mathematics and sciences field (Bedar & Al-Shboul, 2020; S. W. Chan et al., 2020; Sulistiyo & Wijaya, 2020; Wahyudin et al., 2021). This indicates that computer technology has been widely utilized to enhance CT skills.

To date, many researches regarding the enhancement of CT skills using the computer technology in numerous scientific fields such as mathematics and sciences, language, and computer sciences have been widely studied by some researchers. Some studies reported that the utilization of computer technology significantly enhances students' CT skills (Christian P. Brackmann et al., 2017; Choi et al., 2017; Constantinou & Ioannou, 2018; Esteve-Mon et al., 2019; Hooshyar et al., 2021; Jeon & Song, 2019; Jun et al., 2017; Moreno-León et al., 2015; Noh & Lee, 2020; Pérez-Marín et al., 2018; Relkin et al., 2021; Zha et al., 2021; J. H. Zhang et al., 2021). Some studies, however, revealed that the utilization of computer technology significantly does not enhance students' CT skills (Atmatzidou & Demetriadis, 2016; Barrón-Estrada et al., 2022; Bedar & Al-Shboul, 2020; Booth, 2013; Christian Puhlmann Brackmann et al., 2019; J. Chan & Nejat, 2012; Conde et al., 2017; Diago et al., 2021; Jeong & Sung, 2019; Kim, 2021; Kim & Kim, 2016; Kong et al., 2020; Pellas & Vosinakis, 2018; Sulistiyo & Wijaya, 2020; Sun, Hu, et al., 2021a; Wahyudin et al., 2021; Zhao & Shute, 2019). Moreover, a few of studies showed that the involvement of computer technology in learning process has a negative effect in enhancing students' CT skills (del Olmo-Muñoz et al., 2020; Félix et al., 2020; Rodríguez-Martínez et al., 2020; Rose et al., 2017). The reports interpret that the use of computer technology has an inconsistent effect in enhancing students' CT skills. The effect of the utilization of computer technology for students' CT skills required accurate and coherent data which helpful for teacher and lecturer to enhance students' CT skills through mathematics learning process.

Hereinafter, some studies related to the utilization of computer technology for enhancing students' CT skills showed that using computer technology has given moderate effect to the enhancement of students' CT skills (Christian P. Brackmann et al., 2017; Choi et al., 2017; Esteve-Mon et al., 2019; Felicia et al., 2017; Jenkins, 2015; Jeon & Song, 2019; Ridlo et al., 2021; Yulin Zhang et al., 2019). Moreover, several studies revealed that the use of computer technology has strong effect in enhancing students' CT skills (Constantinou & Ioannou, 2018; Jun et al., 2017; Zha et al., 2021; J. H. Zhang et al., 2021). A few of studies, however, showed that the use of computer technology has modest effect to the enhancement of students' CT skills (Barrón-Estrada et al., 2022; Booth, 2013; S. W. Chan et al., 2020; Diago et al., 2021; Guo et al., 2016; Kim, 2021; Moreno-León et al., 2015; Noh & Lee, 2020; Pérez-Marín et al., 2018; Relkin et al., 2021; Sun, Hu, et al., 2021a). On the other side, various studies also showed the opposite results of computer technology in enhancing students' CT skills (Conde et al., 2017; Jeong & Sung, 2019; Kong et al., 2020; Pellas & Vosinakis, 2018; Zhao & Shute, 2019). In conclusion, the use of computer technology had various effect levels to the enhancement of students' CT skills. It indicates that there are students' heterogeneous CT skills in which they have various CT skill levels such as low, moderate, or high. As a consequence, some potential factors such as educational level, group size of intervention, geographical location, learning tool, and subject that can be predicted to vary students' CT skills have to be investigated comprehensively because Lipsey snd Wilson (2001) stated that the existence of moderating factors in the given treatment can vary the resulting effect size.

A lot of relevant studies reporting about the inconsistency of the use of computer technology in enhancing students' CT skills and heterogeneous students' CT skills have to be summarized and synthesized so the process can provide precise and clear information and investigation. Meta-analysis, a series of quantitative methods that can summarize and synthesize several relevant studies related to the strength among two variables or more (Borenstein et al., 2009; Cumming, 2012), can be carried out as an alternative solution of these problems. A few of meta-analysis studies regarding CT skills have been widely carried out by a number of researchers. Some researchers have studied the development of CT skills through games-based learning (Sukirman et al., 2021; Sun, Guo, et al., 2021), and programming curriculum (Lai & Wong, 2022; Li et al., 2020; Scherer et al., 2020; Sun, Hu, et al., 2021b). In addition, few researchers have studied the enhancement of CT skills through scratch web design (Fidai et al., 2020; Lee & Wong, 2021), and educational robots (Yanjun Zhang et al., 2021). Academics achievement and Computational skill had been studied to figure out its affinity (Guan et al., 2021; Lei et al., 2020; Merino-Armero et al., 2020). This meta-analysis study, however, focuses on all learning media used to enhance students' CT skills such as scratch, app inventor, robot programming, website, computer games, and computer software in which scratch, robot programming, computer games, and computer software are the potential computer technologies to enhance students' CT skills.

This recent meta-analysis study aims to summarize and examine few relevant studies related to the enhancement of students' CT skills through computer technology, and investigate and examine a number of moderating factors that can be predicted in varying students' CT skills. In particular, some following research questions are addressed to this current study:

1. How strong is the effect of the use of computer technology in enhancing students' CT skills? Can the interventions using computer technology enhance students' CT skills?
2. Do some moderating factors such as educational level, group size of intervention, geographical location, learning tool, and subject vary the strength of the effect of interventions using computer technology in enhancing students' CT skills so these factors cause students' heterogeneous CT skills?

## METHOD

Method employed to conduct this study was meta-analysis (Borenstein et al., 2009; Cumming, 2012). Random effect model was selected as the estimation model applied in this meta-analysis because the primary studies involved had the heterogeneous characteristics such as educational level, group size of intervention, geographical location, instrument, learning tool, and subject (Fuadi et al., 2021; Jaya & Suparman, 2021; Juandi, Kusumah, Tamur, Perbowo, & Tanu, 2021; Juandi, Kusumah, Tamur, Perbowo, Siagian, et al., 2021; Suparman, Juandi, & Tamur, 2021a, 2021b). According to Cooper et al. (2013) and Hunter and Schmidt (2004), there were seven steps conducted in the meta-analysis process. The steps of meta-analysis are presented in Figure 1.

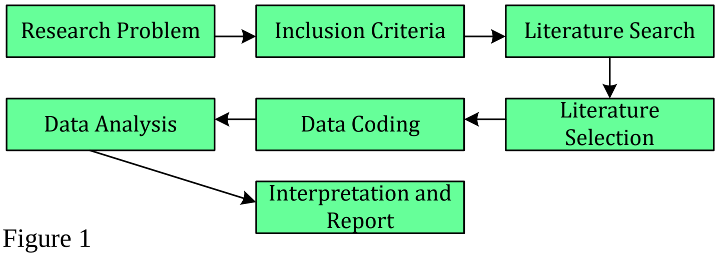


Figure 1
Conducting meta-analysis

**Inclusion criteria**

The search of primary study electronically using the established keywords appeared many potential documents. As a consequence, some inclusion criteria were established to limit the research questions. The inclusion criteria were: (1) the document was published in the period of 2011 – 2021 and indexed by Web of Science, Scopus or Google Scholar, (2) the document was journal article, conference paper, or dissertation written in English, (3) the document reported the sufficient statistical data to compute effect size, (4) population in the document was student in every educational level such as college/university, secondary school, or primary school, (5) intervention in the document was a learning process using computer technology supported by learning tool such as Scratch, robot, code.org, app inventor, computer games or computer software, (6) there were documents that did not use computer technology (7) outcome in the document was CT skills, and (8) quasi-experiment research was the design. The inclusion criteria became the guidelines in searching and selecting the document which would be analyzed in this study.

**Literature search and selection**

Some combinational keywords such as “computational thinking” and “robotics programming curriculum” or “coding-based learning” or “games-based learning” or “web-based learning” were employed to search the document in few databases such as Science Direct, Taylor and Francis, SAGE, Semantic Scholar and Google Scholar. The steps conducted in selecting the document referred to Moher et al. (2009) in which there were four steps consisting of identification, screening, eligibility, and inclusion. The process of document selection is presented in Figure 2.

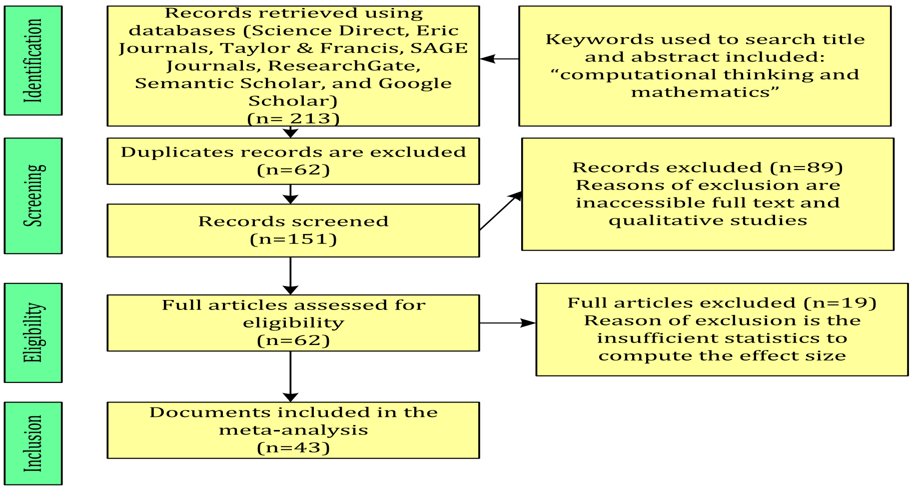


Figure 2
PRISMA flow-diagram of document selection for the meta-analysis

### Data coding

Data coding in the coding sheet contained some information such as author(s), statistics data, moderating factors, document type, publication year, source, database, and indexer. Some moderating factors involved in this study were investigated and examined to make sure their role towards students' CT skills (See Table 1).

Table 1
The distribution of documents based on moderating factors

| Moderating Factors | Groups | Document Frequency | Percentage |
|---|---|---|---|
| Educational Level | Primary School | 19 | 44,19 |
| | Secondary School | 16 | 37,21 |
| | University or College | 8 | 18,60 |
| Geographical Location | America | 11 | 25,58 |
| | Asia | 19 | 44,19 |
| | Europa | 13 | 30,23 |
| Group Size of Intervention | n ≤ 30 | 21 | 48,84 |
| | n ≥ 31 | 22 | 52,16 |
| Learning Tool | Scratch | 10 | 23,26 |
| | Computer Games | 5 | 11,63 |
| | Computer Software | 14 | 32,55 |
| | Robot | 7 | 16,28 |
| | Code.org | 7 | 16,28 |
| Subject | Computer and Programming | 33 | 76,75 |
| | Language | 2 | 4,65 |
| | Mathematics and Science | 8 | 18,60 |

Data coding process involved two experts in meta-analysis study who were statistics lecturer to make sure that the data coding was credible and valid to be used (Vevea et al., 2019). Cohen's Kappa test is used to measure data consistency. McHugh (2012) proposed the formula of the Cohen's Kappa as follows:

$$\kappa = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)}$$

The test result stated that Kappa value was equal to 0, 98 in which it interprets that the agreement level of two coders is almost perfect (McHugh, 2012). It means that the data coding involved in this meta-analysis has been credible and valid to be analyzed.

**Data analysis**

The Hedge's equation was employed to calculate effect size because it could accommodate the studies which had relatively small sample size (Lipsey & Wilson, 2001). Borenstein et al. (2009) formulated the equation as follows:

$$g = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}} \times \left(1 - \frac{3}{4df - 1}\right)$$

Cohen (2018) classified the results into four categories. Starting from weak to strong, g = 0,00 – 0,20 is considered weak, g = 0,21 – 0,50 is modest, g = 0,51- 1,00 is moderate, and finally g > 1,00 is measured as strong. Subsequently, another Z test was also used to examine the significance of the interventions using computer technology on students' CT skills (Borenstein et al., 2009). In addition, to examine the significance of moderating factors in causing students' heterogeneous CT skills, the Cochran's Q test was used (Higgins et al., 2003).

Hereinafter, the statistics data in meta-analysis is said to become publication bias (Cooper et al., 2013). As a consequence, to ensure that the statistics data was avoided from the publication bias, funnel plot analysis and the Egger's regression test were carried out (Rothstein et al., 2005). The result of funnel plot analysis in Figure 3 shows that the distribution of the collection of effect size data was symmetrical. It means that the effect size data from every document involved in this study was resistant to publication bias. To ensure distributed effect size data was symmetrical, Egger's regression test was conducted. The results of Egger's regression test showed that t-value was 1,167 and p-value was 0,250. It proved strong evidence that the data was symmetrical. It interprets that statistics data collected did not indicate a significant publication bias.

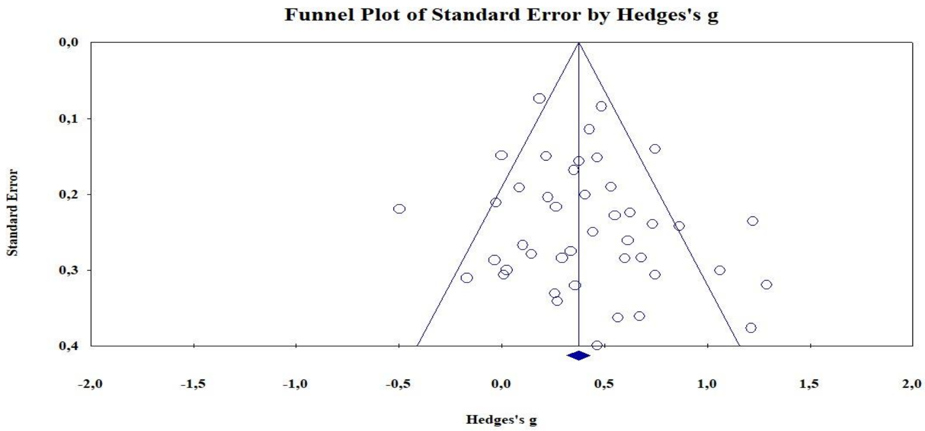


Figure 3
The distribution of the collection of effect size data

## FINDINGS

### Effect Size on Overall Computational Thinking Skill

The reports of document search indicated that from 43 documents, 23 documents came from google scholar, followed by eight documents from semantic scholar, six documents from research gate, three documents from Taylor & Francis, two documents from SAGE, and one document from science direct. In addition, these documents consisted of one dissertation, nine conference papers, and 33 journal articles (See Figure 4).

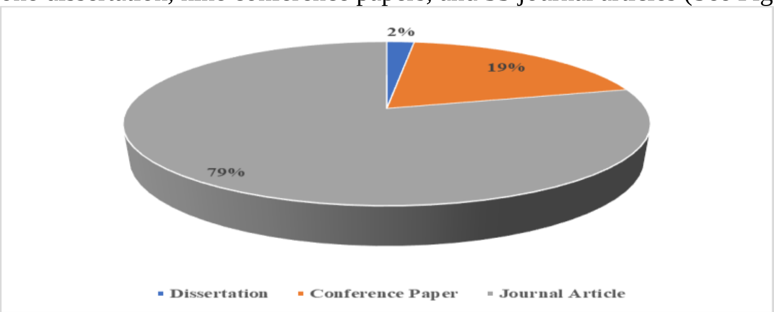


Figure 4
Document type

Figure 5 shows that the development of the number of documents related to the utilization of computer technology on students' CT skills tended to soar from 2013 to 2021. In particular, the number of documents moderately increased in the period of 2013 – 2017. Moreover, the number of documents sharply jumped in the period of 2018 – 2019 and 2020 – 2021. Meanwhile, the number of documents slightly decreased in the period of 2017 – 2018. Moreover, the number of documents sharply fallen in the period of 2019 – 2020.

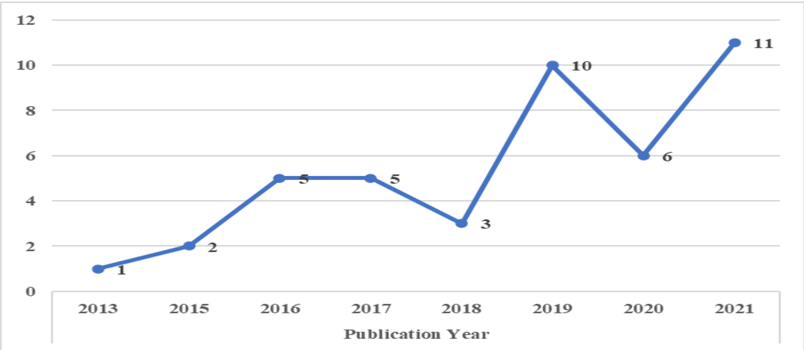


Figure 5
Number of documents based on publication year

| Study name | Hedges's g | Standard error | Variance | Lower limit | Upper limit | Z-Value | p-Value |
|---|---|---|---|---|---|---|---|
| | Statistics for each study | | | | | | |
| Noh & Lee, 2019 | 0,427 | 0,115 | 0,013 | 0,203 | 0,652 | 3,728 | 0,000 |
| Atmatzidou & Demetriadis, 2016 | 0,217 | 0,150 | 0,022 | -0,077 | 0,510 | 1,447 | 0,148 |
| Jun et al., 2016 | 1,223 | 0,236 | 0,056 | 0,761 | 1,685 | 5,188 | 0,000 |
| Moreno-León, 2015 | 0,465 | 0,152 | 0,023 | 0,167 | 0,764 | 3,059 | 0,002 |
| Pérez-Marin et al., 2018 | 0,406 | 0,201 | 0,040 | 0,013 | 0,799 | 2,026 | 0,043 |
| Çak?r, 2021 | 0,000 | 0,149 | 0,022 | -0,292 | 0,292 | 0,000 | 1,000 |
| Kim & Kim, 2016 | 0,272 | 0,341 | 0,117 | -0,398 | 0,941 | 0,795 | 0,426 |
| Zhang et al., 2021 | 1,061 | 0,301 | 0,091 | 0,471 | 1,651 | 3,526 | 0,000 |
| Kim, 2021 | 0,336 | 0,275 | 0,076 | -0,203 | 0,875 | 1,221 | 0,222 |
| Constantinou & Ioannou, 2018 | 1,214 | 0,377 | 0,142 | 0,476 | 1,952 | 3,223 | 0,001 |
| Esteve-Mon et al., 2019 | 0,747 | 0,141 | 0,020 | 0,471 | 1,023 | 5,307 | 0,000 |
| Sulistiyo & Wijaya, 2019 | 0,264 | 0,217 | 0,047 | -0,161 | 0,690 | 1,218 | 0,223 |
| Kong et al., 2020 | 0,102 | 0,267 | 0,071 | -0,421 | 0,626 | 0,383 | 0,702 |
| Relkin et al., 2021 | 0,485 | 0,085 | 0,007 | 0,319 | 0,650 | 5,732 | 0,000 |
| Choi et al,, 2016 | 0,626 | 0,225 | 0,051 | 0,186 | 1,067 | 2,785 | 0,005 |
| Jeon & Song, 2019 | 0,746 | 0,307 | 0,094 | 0,145 | 1,347 | 2,433 | 0,015 |
| Pellas & Vosinakis, 2018 | 0,146 | 0,279 | 0,078 | -0,401 | 0,692 | 0,522 | 0,602 |
| Zha et al., 2020 | 1,288 | 0,319 | 0,102 | 0,662 | 1,914 | 4,033 | 0,000 |
| Hooshyar et al., 2021 | 0,550 | 0,228 | 0,052 | 0,104 | 0,997 | 2,415 | 0,016 |
| Olmo-Mu~noz et al., 2020 | -0,496 | 0,220 | 0,048 | -0,926 | -0,066 | -2,259 | 0,024 |
| Brackmann et al., 2019 | 0,357 | 0,320 | 0,103 | -0,271 | 0,985 | 1,114 | 0,265 |
| Witherspoon et al., 2017 | 0,184 | 0,074 | 0,006 | 0,039 | 0,330 | 2,483 | 0,013 |
| Witherspoon & Schunn, 2019 | 0,375 | 0,156 | 0,024 | 0,069 | 0,681 | 2,400 | 0,016 |
| Zhao & Shute, 2019 | 0,025 | 0,300 | 0,090 | -0,563 | 0,614 | 0,085 | 0,933 |
| Rodriguez-Martinez et al., 2019 | -0,034 | 0,287 | 0,082 | -0,597 | 0,528 | -0,120 | 0,905 |
| Brackmann et al., 2017 | 0,863 | 0,242 | 0,059 | 0,388 | 1,338 | 3,562 | 0,000 |
| Diago et al., 2021 | 0,464 | 0,400 | 0,160 | -0,319 | 1,248 | 1,161 | 0,246 |
| Chan et al., 2020 | 0,224 | 0,204 | 0,042 | -0,176 | 0,624 | 1,097 | 0,273 |
| Conde et a., 2017 | 0,085 | 0,191 | 0,037 | -0,289 | 0,460 | 0,446 | 0,655 |
| Wahyudin et al., 2021 | 0,565 | 0,363 | 0,132 | -0,145 | 1,276 | 1,559 | 0,119 |
| Ridlo et al., 2020 | 0,734 | 0,239 | 0,057 | 0,264 | 1,203 | 3,064 | 0,002 |
| Félix et al., 2020 | -0,026 | 0,211 | 0,045 | -0,441 | 0,388 | -0,125 | 0,900 |
| Zhang et al., 2019 | 0,600 | 0,285 | 0,081 | 0,042 | 1,159 | 2,108 | 0,035 |
| Rose, 2017 | -0,168 | 0,311 | 0,096 | -0,777 | 0,440 | -0,542 | 0,588 |
| Barrón?Estrada et al., 2021 | 0,258 | 0,331 | 0,109 | -0,389 | 0,906 | 0,782 | 0,434 |
| Jeong & Sung, 2019 | 0,011 | 0,306 | 0,094 | -0,590 | 0,611 | 0,035 | 0,972 |
| Lopez et al., 2021 | 0,531 | 0,190 | 0,036 | 0,158 | 0,904 | 2,788 | 0,005 |
| Booth, 2013 | 0,294 | 0,284 | 0,081 | -0,263 | 0,851 | 1,034 | 0,301 |
| Felicia et al., 2017 | 0,614 | 0,261 | 0,068 | 0,103 | 1,126 | 2,355 | 0,019 |
| Jenkins, 2015 | 0,679 | 0,284 | 0,081 | 0,123 | 1,235 | 2,392 | 0,017 |
| Guo et al., 2016 | 0,352 | 0,168 | 0,028 | 0,022 | 0,681 | 2,090 | 0,037 |
| Sun et al., 2021 | 0,444 | 0,250 | 0,063 | -0,047 | 0,934 | 1,774 | 0,076 |
| Bedar, 2020 | 0,672 | 0,361 | 0,130 | -0,035 | 1,379 | 1,863 | 0,062 |
| | 0,401 | 0,050 | 0,003 | 0,303 | 0,500 | 7,961 | 0,000 |

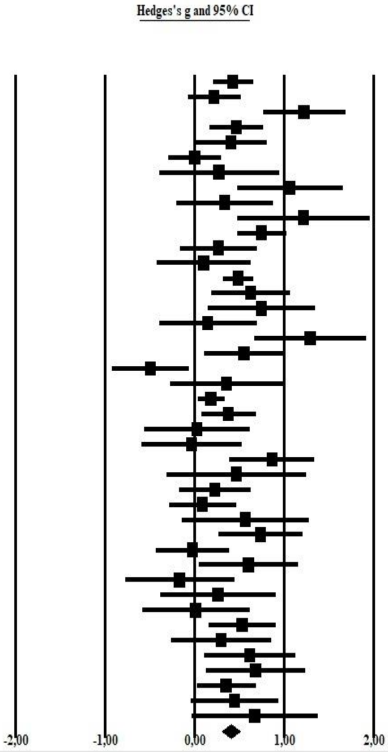


Figure 6
Forest plot of effects of interventions using computer technology on students' CT skills

Effect size of each document in Figure 6 was categorized by the classification of effect size. The classification is presented in Figure 7.

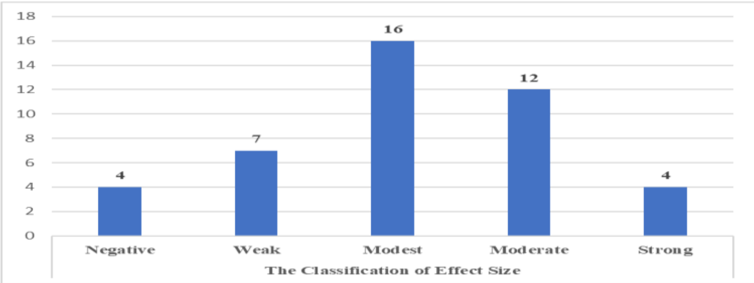


Figure 7
The number of documents based on the level of effect size

Figure 6 shows that overall, the various interventions utilizing computer technology in learning process had modest effect size (g = 0,401) on students' CT skills. In addition, Figure 7 also shows that most of documents had modest effect size. In the overall effect size, the significant value of the Z test was less than 0,05. It means that a lot of interventions using computer technology in learning process significantly enhance students' CT skills. This indicates that the utilization of computer gave huge positive impact on students' CT skills.

Hereinafter, there were four documents authorized by del Olmo-Muñoz et al. (2020), Rodríguez-Martínez et al. (2020), Félix et al. (2020), and Rose et al. (2017) reporting that some interventions using computer technology in learning process had negative effect size on students' CT skills. Particularly, they revealed some reasons regarding the use of computer technology having negative effect size on students' CT skills (See Table 2).

Table 2
Some reasons of the low CT skills in intervention class

| Documents/Authors | Reasons |
|---|---|
| Rodríguez-Martínez et al. (2019) | ▪ Students' low experience on CT<br>▪ The development of students' computational concept that is not applied in the elementary education |
| Félix et al. (2020) | ▪ Short intervention periods<br>▪ A minimum time to practice CT skills |
| Rose et al. (2017) | ▪ Scratch Jr application needs more time to finish every mission than Lightbot application<br>▪ Scratch Jr application is more difficult than Lightbot application |
| Olmo-Muñoz et al. (2020) | ▪ Students' low CT skills<br>▪ There is impact of some factors such as motivation and gender difference in the class |

**Analysis of moderating factors**

This study investigated and examined some moderating factors which had potency to cause students' heterogeneous CT skills. Table 3 shows that the significant value of the Q Cochrane test for each moderating factor was more than 0,05. These results mean that educational level, group size of intervention, geographical location, learning tool, and subject are not moderating factors causing the heterogeneity of students' CT skills. It indicates that the levels are not moderated by those factors.

Heterogeneity analysis results using Q Cochrane test on the moderating factors are shown in Table 3.

Table 3
The results of heterogeneity analysis

| Moderating Factors | Group | Studies Number | Effect Size | Heterogeneity $Q_b$ | df | P-value |
|---|---|---|---|---|---|---|
| Educational Level | Primary School | 19 | 0,437 | 0,384 | 2 | 0,825 |
| | Secondary School | 16 | 0,384 | | | |
| | University or College | 8 | 0,359 | | | |
| Geographical Location | America | 11 | 0,325 | 2,421 | 2 | 0,298 |
| | Asia | 19 | 0,499 | | | |
| | Europe | 13 | 0,347 | | | |
| Group Size of Intervention | n ≤ 30 | 21 | 0,436 | 0,258 | 1 | 0,612 |
| | n ≥ 31 | 22 | 0,382 | | | |
| Learning Tool | Computer Games | 5 | 0,449 | 6.912 | 4 | 0,141 |
| | Computer Software | 14 | 0,425 | | | |
| | Robot | 7 | 0,310 | | | |
| | Scratch | 10 | 0,581 | | | |
| | Code.org | 7 | 0,175 | | | |
| Subject | Computer and Programming | 33 | 0,389 | 4,709 | 2 | 0,095 |
| | Language | 2 | 0,961 | | | |
| | Mathematics and Science | 8 | 0,343 | | | |

## DISCUSSION

### Effectiveness of the utilization of computer technology on students' CT skills

This study found that the use of computer technology in learning process had modest positive effect on students' CT skills in which the utilization of computer technology significantly enhanced students' CT skills through learning process. Some meta-analysis studies also revealed that the interventions using Scratch in learning process significantly enhanced students' CT skills (Fidai et al., 2020; Lee & Wong, 2021). Fidai et al. (2020) reported that Scratch interventions have moderate positive effect (g = 0,67; p-value < 0,05) on students' CT skills. Yanjun Zhang et al. (2021) also revealed that the interventions of educational robots significantly improve students' CT skills in which educational robots have modest positive effect (g = 0,48; p-value < 0,05) on students' CT skills.

Some meta-analysis reports also revealed that the interventions using computer programming in learning process significantly enhanced students' CT skills (Guan et al., 2021; Lai & Wong, 2022; Merino-Armero et al., 2020; Scherer et al., 2020; Sun, Hu, et al., 2021b). Scherer et al. (2020) reported that computer programming interventions have moderate positive effect (g = 0,814; p-value < 0,001) on students' CT skills. Meanwhile, Lai and Wong (2022) reported that programming interventions have moderate positive effect (g = 0,562; p-value < 0,01) on students' CT skills. On the other hand, Sun, Hu, et al. (2021b) reported that programming activities have moderate positive effect (g = 0,601; p-value < 0,001) on students' CT skills.

A few of meta-analysis literatures also revealed that the interventions of computer games in learning process significantly enhanced students' CT skills (Guan et al., 2021;

Merino-Armero et al., 2020; Sun, Guo, et al., 2021). Sun, Guo, et al. (2021) reported that the interventions of educational games have moderate positive effect ($g = 0,766$; p-value $< 0,05$) on students' CT skills. Meanwhile, Merino-Armero et al. (2020) reported that the interventions of game-based learning have moderate positive effect ($g = 0,709$; p-value $< 0,01$) on students' CT skills. On the other hand, Guan et al. (2021) reported that the interventions of game-based learning have strong positive effect ($g = 1,781$; p-value $< 0,03$) on students' CT skills.

These reports provide strong evidence that the interventions using computer technology such as Scratch, robotic programming, computer programming, and computer games can enhance students' CT skills. Students who have high CT skills can support them to obtain the highest academic achievement. H. Lei et al. (2020) revealed that there was a significant relationship between computational thinking and academic achievement. It means that students can get high academic achievements when they have high CT skills. As a consequence, students who still have low CT skills have to be intervened by learning process using computer technology.

The interventions conducted on the documents in this study use some learning tools such as computer games, computer software, robot, Scratch, and code.org to enhance students' CT skills. It shows that the use of computer technology in learning process is able to enhance students' CT skills. The fast development of computer technology provides digitalization and computerization in the modern society life in the 21st century (Sanabria & Arámburo-Lizárraga, 2017; Silber-Varod et al., 2019). The enhancement of students' CT skills utilizing computer technology can support students to adapt with the rapid development of information and computer technology in the society life (Hsu et al., 2018).

The development of computer technology in the 21st century extremely enables students to enhance their CT skills through learning process, especially in mathematics learning. Mathematics is a scientific field requiring students to have problem-solving skills (NCTM, 2000), in which problem-solving skills facilitate students to get the best academic achievement. ISTE and CSTA (2011) defined CT as a problem-solving process comprising some criteria such as (1) formulating problems using computer and other tools to solve it, (2) organizing and analyzing the data logically, (3) representing the data by abstracting such as model and simulation, (4) automating the solution by algorithm thinking, (5) identifying, analyzing, and applying the solution to get maximum combination of steps, and (6) generalizing and transferring the problem-solving process to various problems. It means that by learning mathematics, students' CT skills should be enhanced to obtain the best mathematics academic achievement. This indicates that the interventions using computer technology in mathematics learning can support students to achieve the best mathematics learning outcomes by enhancing their CT skills.

Hereinafter, some documents reported that few interventions using computer technology in learning process had negative effect on students' CT skills. Rodríguez-Martínez et al. (2020) revealed that students who have not carried out some problems related to computational thinking will be difficult to finish the problems. In addition, students' CT skills in the elementary education have not developed. To enhance CT skills, students need the long intervention period in which the intervention conducted in long time will provide the chance for teacher and student to optimize the learning process (Félix et al., 2020). Félix et al. (2020) also revealed that teachers and students still have difficulties when they use technology-based learning media. As a consequence, the use of computer technology in learning process will appear new problems for teachers and students (Galy et al., 2011).

Students do not have early knowledges, so they can't understand and solve the problems related to previous materials (Dunlosky et al., 2013). As a result, they can't solve the problems even if they have high CT skills. del Olmo-Muñoz et al. (2020) reported that female students' CT skills are lower than male students' CT skills because male students are more intensive in playing games than female students. Some literatures also showed that the interventions of game-based learning can significantly enhance students' CT skills (Guan et al., 2021; Merino-Armero et al., 2020; Sun, Guo, et al., 2021). In addition, Buitrago Flórez et al. (2017) revealed that motivation have the crucial role in learning process. Students will be difficult to understand work-flow and thinking step in CT when they have low motivation (Iversen et al., 2018; Suparman, Juandi, & Herman, 2021). Therefore, teachers as facilitators in learning process have to consider the factors that can make students to be difficult to enhance their CT skills.

**Moderating factors**

*Educational level*

The results revealed that educational level was not moderating factor causing students' heterogeneous CT skills. Some meta-analysis studies have proven that the heterogeneity of students' CT skills were not moderated by the factor of education level (Fidai et al., 2020; Merino-Armero et al., 2020). Meanwhile, other meta-analysis studies revealed that there were different CT skills between elementary students, secondary students, and college students in which elementary students had more high CT skills than secondary students and college students (Lai & Wong, 2022; Lei et al., 2020; Sun, Hu, et al., 2021b; Yanjun Zhang et al., 2021). The findings of this study indicate that students' CT skills in every educational level are not different in which the cognitive development of students in every grade level is suitable to the requirement of learning materials which students have to mastery in enhancing their CT skills.

For educational level factor, the use of computer technology in the primary school, secondary school, and college had modest positive effect on students' CT skills. As a result, the interventions effect size for primary students was higher compared to secondary students and college students' CT skills. This indicates that the interventions using computer technology on primary students' CT skills are more effective than the interventions using computer technology on secondary or college students' CT skills.

*Geographical location*

The results also revealed that the students' heterogeneous CT skills was not moderated by the factor of geographical location. It indicates that the development of computer technology in America, Asia, and Europe has prevalent deployment, so teachers and students can use it to enhance students' CT skills in learning process. Whereas several meta-analysis studies revealed that geographical location significantly moderated the heterogeneity of students' CT skills (Guan et al., 2021; Lei et al., 2020). Lei et al. (2020) reported that there were different CT skills between eastern students and western students, which reported eastern students had higher. In contrast, Guan et al. (2021) reported the exact opposite.

For geographical location factor, the interventions using computer technology among America, Asia and Europe were varied. The report said that Asia had the highest effect size among America and Europe. It indicated that the implementation of intervention using computer technology was more successful in Asia.

*Group size of intervention*

The results revealed that group size of intervention was not moderating factor causing students' heterogeneous CT skills. It indicates that teachers have a sufficient pedagogical and professional skills, so they can accommodate student needs in learning process utilizing computer technology in small classroom or large classroom. A few of meta-analysis reports, however, revealed that group size of intervention significantly moderated students' heterogeneous CT skills (Sun, Guo, et al., 2021; Sun, Hu, et al., 2021b). There were different CT skills between students who learnt in the small classroom dan students who learnt in the large classroom in which students who learnt in the small classroom had more high CT skills than students who learnt in the large classroom (Sun, Guo, et al., 2021; Sun, Hu, et al., 2021b).

For group size of intervention factor, the use of computer technology in the small classroom ($n \leq 30$ participants) and large classroom ($n \geq 31$ participants) had modest positive effect on students' CT skills. However, the effect size of interventions using computer technology on students' CT skills in the small classroom was higher than the effect size of interventions using computer technology on students' CT skills in the large classroom. It indicates that the interventions using computer technology on students' CT skills in the small classroom are more effective than the interventions using computer technology on students' CT skills in the large classroom.

*Learning tool*

The results also revealed that the students' heterogeneous CT skills was not moderated by the factor of learning tool. It indicates that there are not different CT skills between students who learnt using Scratch and students who learnt using robot, computer games, code.org, and computer software. In contrast, some meta-analysis literatures revealed that learning tool significantly moderated the heterogeneity of students CT skills (Merino-Armero et al., 2020; Sun, Hu, et al., 2021b). Sun, Hu, et al. (2021b) reported that students who learnt using website such as code.org had more high CT skills than students who learnt using another learning tool such as Scratch, robot, and unplugged programming. On the other hand, Merino-Armero et al. (2020) reported that students who learnt using physical programming had more high CT skills than students who learnt using video games, puzzle, and simulation.

For learning tool factor, positive marks were noted in the interventions using computer games, computer software, and robot in learning process. Meanwhile, the interventions using Scratch in learning process had moderate positive effect on students' CT skills. On the other hand, the interventions using code.org in learning process had weak positive effect on students' CT skills. As a consequence, the effect size of interventions using Scratch on students' CT skills was higher than the effect size of interventions using computer games, computer software, robot, and code.org. It indicates that the interventions using Scratch on students' CT skills are more effective than the interventions using computer games, computer software, robot, and code.org.

*Subject*

The results revealed that subject was not moderating factor causing students' heterogeneous CT skills. It indicates that the enhancement of students' CT skills using computer technology in mathematics and sciences, language, and computer and programming is not different. Lei et al. (2020) also revealed that subject did not moderate the heterogeneity of students' CT skills. A few of meta-analysis reports, however, revealed that students' heterogeneous CT skills were moderated by the factor of subject (Merino-Armero et al., 2020; Sun, Hu, et al., 2021b). Sun, Hu, et al. (2021b) revealed that students' CT skills in the field of STEM were higher than students' CT skills in some subjects such as computer sciences, mathematics, music, language, biology, and physics. Meanwhile, Merino-Armero et al. (2020) revealed that students' CT skills in the subject of social sciences and art were higher than students' CT skills in several subjects such as programming, sciences, robotics, mathematics, English, STEAM, informatics, and dance.

For subject factor, the interventions using computer technology in the language had moderate positive effect. However, the interventions using computer technology in the computer and programming, and mathematics and sciences had modest positive effect on students' CT skills. It shows that the effect size of interventions using computer technology on students' CT skills in the language was higher than the effect size of interventions using computer technology on students' CT skills in the computer and programming, and mathematics and sciences. It indicates that the interventions using computer technology on students' CT skills in the language are more effective than the interventions using computer technology on students' CT skills in the computer and programming, and mathematics and sciences.

## CONCLUSION

This study provides some information related to the interventions using computer technology in learning process on students' CT skills. The interventions utilizing computer technology have modest positive effect on students' CT skills in which the interventions using computer technology significantly enhance students' CT skills ($g = 0{,}401$; p-value $< 0{,}05$). It means that the involvement of computer technology in mathematics learning can support teachers or lecturers in enhancing students' CT skills. In addition, some factors such as educational level, geographical location, group size of intervention, learning tool, and subject do not moderate the heterogeneity of students' CT skills. It means that the level of students' CT skills enhanced by using computer technology is not caused by the factors. It indicates that there are other moderating factors that should be investigated and examined in which they extremely enable to moderate students' heterogeneous CT skills.

## IMPLICATION

Problem-solving is one of the important skills that students have to mastery in solving math problems, so they can achieve the high mathematics academic outcome. Meanwhile, CT skills are defined as problem-solving process. It means that students must have high CT skills to get the best mathematics academic achievement. The fast development of technology in the 21st – century extremely enables teacher and student to use computer technology in enhancing their CT skills. This study also reveals that the interventions using computer technology such as Scratch, robot, code.org, computer games, and computer software significantly enhance students' CT skills. It means that the computer technologies can be utilized in conducting the interventions in mathematics learning to enhance students' CT skills.

## LIMITATION AND RECOMMENDATION

There are some limitations in this study. This study has not investigated and examined other moderating factors such as intervention period, number of users in using a computer, and learning approach or model because researchers have some difficulties to get access of the information of the moderating factors. The moderating factors extremely enable to cause the heterogeneity of students' CT skills. In addition, researchers only can get some documents in which its primary studies are conducted in Asia, America, and Europe, but primary studies related to the interventions using computer technology on students' CT skills conducting in Africa and Australia have not been found. As a consequence, the documents obtained in this study have not represented the reports regarding the effect of interventions utilizing computer technology on students' CT skills in the world. Therefore, for further relevant meta-analysis studies, researchers have to investigate and examine other moderating factors such as intervention period, number of users using a computer, and learning approach or model. Researchers also should involve the documents which can represent the reports regarding the interventions using computer technology on students' CT skills in the world.

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