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# The impact of STEM attitudes and computational thinking on 21st-century via structural equation modelling

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**ABSTRACT**

Based on the study, computational thinking skills are influenced by science, technology, engineering and mathematics (STEM) skills, and there is a relationship between computational thinking skills and 21st-century skills. However, studies related to STEM attitudes, computational thinking and their impact on 21st-century skills are still very few and limited. The purpose of our study was to examine the impact of STEM attitudes and computational thinking on 21st-century. This research uses a quantitative approach. The participants of this study were students of a vocational school in Bantul Regency, Yogyakarta, Indonesia (N=290). Research data in STEM attitude, computational thinking, and 21st-century skills using a questionnaire. The data were analyzed using structural equation modeling techniques using the Smart PLS application. The results of the study obtained several findings, including: the model proposed in this study was valid; STEM attitude has a positive and significant effect on computational thinking; and computational thinking has a positive and significant effect on 21-st century skills. It can be argued that when STEM attitudes and computational thinking are more positive, 21-st century skills will improve. These findings have implications that curriculum development and STEM learning practices have to develop students' computational thinking skills and 21st-century skills, especially in vocational schools.



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## 1. INTRODUCTION

STEM-based learning (science, technology, engineering, and mathematics) is believed to train students' abilities in dealing with problems in the 21st-century [1], [2]. STEM learning uses an interdisciplinary approach that integrates academic concepts based on real-world situations through the application of science, technology, engineering and mathematics [3]–[6]. Through this learning, students will be trained to solve problems better; besides that, students are expected to become innovators, inventors, independent workers, logical thinkers, creative, collaborative and technological literacy [7].

Viewed from the perspective of competence, one of the skills that need to be developed to face the challenges of the 21st-century is computational thinking [8]–[10]. Computational thinking is also believed to improve students' problem-solving skills, especially in the 21st-century [11]. Computational thinking is an essential skill taught through various subjects. By having these skills, students will have the ability to formulate, solve, and reveal solutions through computer science-based information processing required by most other scientific fields [12]. In addition, these skills will also help students solve problems using technology (technological literacy) that they live in daily [13].

Based on several studies, STEM-based learning influences the development of computational thinking skills. In other words, this ability can be enhanced through STEM-based learning [14]–[17]. This shows that students' ability to combine science, technology, engineering and math skills is directly proportional to their computational thinking ability [18]. Viewed from the attitude aspect, learning attitudes towards STEM can significantly predict computational thinking skills [19]. Furthermore, in other studies, computational thinking skills are part of 21st-century skills [20]. It can be argued that computational thinking skills can influence 21st-century skills [21].

Based on this study, it is clear that there is a link between STEM and computational thinking skills and the relationship between computational thinking and 21st-century skills. The results of other studies also show that STEM and computational thinking show a linear relationship [19], [22]–[24]. However, studies related to STEM attitudes, computational thinking and their impact on 21st-century skills are still very few and limited. The domain understudy is focused on the affective aspect. Based on the results of international studies, it was found that skills in the cognitive domain are strongly influenced by the affective domain [25]–[27]. So that the affective domain of STEM attitudes, computational thinking, and 21st-century skills is very important to study. This study focuses on the effect of STEM attitudes on computational thinking skills and 21st-century skills and the influence of computational thinking skills on 21st-century skills.

This research has been carried out in one of the vocational schools in Indonesia. This is because the learning culture in vocational schools emphasizes problem solving skills, producing new products, critical thinking, creative, systematic, communicative, and reflective. All of that can be implemented through STEM learning. In 2019, STEM was used in professional development program for three years, which involved 34 vocational school in various region in Indonesia [28]. This program is expected to improve learning practices that have led to science in the revised 2013 and STEM complements the concept of thinking through changes in vocational teacher mindset. However, STEM learning has not been widely applied in various vocational schools in Indonesia [28]. This also has implications for the application of 21st-century skills-oriented learning that has not been maximized [28]. So there needs to be a change in curriculum orientation, as well as training for teachers on STEM learning and 21st-century skills. Through this research, it is possible to make a practical contribution that STEM can have an influence on 21st-century skills through the development of computational thinking skills in vocational school learning. The objectives of this study include: i) Developing a valid conceptual model related to STEM attitude, computational thinking, and 21-st century skills; ii) Find the impact of STEM attitudes and computational thinking on 21st-century skills. Based on the research objectives, several research hypotheses were: i) STEM attitude has a positive and significant effect on 21-st century skills (H1); ii) STEM attitude has a positive and significant effect on computational thinking (H2); iii) Computational thinking has a positive and significant effect on 21-st century skills (H3).

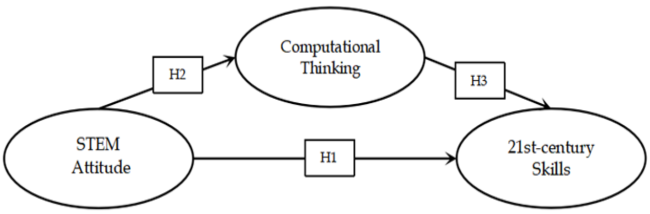


Figure 1. Research model

## 2. RESEARCH METHOD

This research is a quantitative descriptive study with a correlation design. The correlation design used aims to identify variables that can predict an outcome using a structured equation model (SEM). One variable is set as a predictor in this design and another variable as a criterion variable [29]. In this study, STEM attitude was determined as a predictor variable, computational thinking skills as a mediating variable, and 21-st century skills as a criterion variable. The participants of this study were 290 students from the vocational school (SMKN 1 Pajangan) Bantul Regency, Yogyakarta Special Region Province, Indonesia. Participants were selected using the survey method. Of the participants, 29.31% were female (f=85) and 70.69% were male (f=205). Of the students, 31.03% were in class X (f=90), 36.21% were in class XI (f=105), and 32.76% of the participants were students of class XII (f=95). The distribution of research sample data is shown in Table 1.

Table 1. The distribution of the gender and grade participants

| Grades | Gender | | N |
|---|---|---|---|
| | Male | Female | |
| X Grade | 61 | 29 | 90 |
| XI Grade | 78 | 27 | 105 |
| XII Grade | 66 | 29 | 95 |
| Total | 205 | 85 | 290 |

The data collection tools used in this study include the STEM Attitude, 21st-skills Scale, and the computational thinking Scale. The STEM Attitude and 21st-skills Scale were developed by Unfried which consists of four factors and the development has met Lawshes' content validity ratio (CVR), and validity is made from scores on instrument items and subscales [30]. These factors include science consisting of eight items, technology/technique consisting of 11 items, mathematics consisting of nine items, and 21st-century skills consisting of 13 items. Each item has a 5-point Likert scale. Interpretation of instrument reliability as measured by Cronbach's alpha refers to interval which is showed in Table 2.

Table 2. Cronbach's alpha interval and interpretation

| Cronbach's alpha interval | Interpretation |
|---|---|
| 0.80-1.00 | Very high |
| 0.60-0.79 | High |
| 0.40-0.59 | Moderate |
| 0.20-0.39 | Low |
| 0.00-0.19 | Very low |

Cronbach's alpha reliability coefficient for the scale in the original study was 0.83 for science, 0.84 for technology/technique, 0.85 (very high) for mathematics, and 0.87 (very high) for 21st-century skills. While in this study, the CRONBACH alpha reliability coefficient was obtained 0.764 (high) for the STEM Attitudes scale and 1,000 for 21st-century skills. computational thinking Scale was developed by Ertugrul-Akyol [31]. This scale has three factors which include computational thinking (CT1) consisting of 15 items; robotic coding and software (CT2) consisting of 10 items; and professional development and career planning (CT3) consisting of 5 items. Each item has a 5-point Likert scale. Cronbach's alpha reliability coefficient for the scale in the original study was 0.86 (Very high). While in this study, the Cronbach alpha reliability coefficient obtained was 0.898 (Very high).

Data analysis in this study uses SEM techniques assisted by SmartPLS 3 software. The first analysis is to assess the proposed path model has a good level of validity and reliability. There are four indicators that must be tested to get a valid and reliable model: i) Reliability indicators are evaluated using loadings of 0.70 and above; ii) Internal consistency reliability is evaluated using composite reliability (CR) of 0.70 and above; iii) Convergent validity was evaluated using average variance extracted (AVE) from 0.50 and above; iv) While the discriminant validity was evaluated using the heterotrait monotrait correlation ratio (HTMT) of 0.90 and below [32]. In addition, to check whether the model produces a good fit, several fit statistics are used, including: i) Standardized Root Mean Square Residual (SRMR) <0.10 or 0.08 [33]; ii) Normal fit index (NFI) close to 1 [34]; iii) Outer loading of 0.7 and above [35]. The second analysis assesses the relationship between variables proposed in the theoretical framework by using a bootstrapping approach. On the other hand, this analysis is used to answer the hypotheses that have been proposed previously

## 3. RESULTS AND DISCUSSION

### 3.1. Assessment of path model

The first step is to determine that the proposed model is valid, reliable, and fit criteria. Based on the calculation results, the model has met the validity standards (convergent and discriminant) and has met the reliability standards. The value of factor loadings indicates this, Cronbach's alpha, CR, AVE and HTMT as required. Meanwhile, for the fit indices model, the value of NFI=0.8 (NFI value is close to 1), SRMR value=0.090 (SRMR<0.10), and the value of outer loading on each factor on the latent variable is more than 0.7. Based on these results, it can be concluded that all eligibility criteria meet the value of the feasibility test criteria. The assessment results of the validity, reliability and fit criteria of the path model are shown in Table 3 and Table 4. By getting a path model with a satisfactory level of validity and reliability and meets the fit criteria. Then, researchers can perform further analysis, namely, testing the hypothesis.

Table 3. Results of the assessment of the path model based on validity and reliability

| Variables | Indicators | Reliability: Indicator reliability — Factor loadings (FL) FL>0.70 | Reliability: Internal consistency reliability — Cronbach's alpha α ≥0.70 | Reliability: Internal consistency reliability — CR CR>0.70 | Validity: Convergent validity — AVE AVE>0.05 | Validity: Discriminant validity — HTMT HTMT<0.90 |
|---|---|---|---|---|---|---|
| STEM attitudes | Mathematics (Math) | 0.755 | 0.764 | 0.859 | 0.672 | Acceptable |
| | Science | 0.840 | | | | |
| | Technology/Engineering (Tech/Eng) | 0.860 | | | | |
| Computational thinking | Computational thinking (CT1) | 0.912 | 0.898 | 0.936 | 0.830 | Acceptable |
| | Robotic coding and software (CT2) | 0.916 | | | | |
| | Professional development and career planning (CT3) | 0.906 | | | | |
| 21st-century skills | 21-century skills | 1.000 | 1.000 | 1.000 | 1.000 | Acceptable |

Table 4. Structural equation model fit indices

| Latent variable | Indicator | Factor loading (FL) >0.70 | Fit Value: SRMR<0.10 | Fit Value: NFI (NFI value close to 1) | Decision |
|---|---|---|---|---|---|
| STEM attitudes | Mathematics (Math) | 0.755 | 0.090 | 0.080 | The model is fit |
| | Science | 0.840 | | | |
| | Technology/Engineering (Tech/Eng) | 0.860 | | | |
| Computational thinking | Computational thinking (CT1) | 0.912 | | | |
| | Robotic coding and software (CT2) | 0.916 | | | |
| | Professional development and career planning (CT3) | 0.906 | | | |
| 21st-century skills | 21st-century skills | 1.000 | | | |

### 3.2. Summary of effect

This section describes the relationship between variables proposed in the theoretical framework. Through this analysis will answer the research hypotheses that have been proposed. The relationship of research hypothesis of each variable was analyzed using Pearson correlation analysis using parametric statistics. The hypotheses developed in this study include seeing the influence between the variables studied. Based on the results of the analysis, it was found that: i) STEM Attitude had a positive and significant effect on 21-st century skills (H1). The p-value indicates this (0.000) <0.05, and the path coefficients value is positive (0.347). while the correlation coefficient value (Rsquare=0.504) means that the effect of STEM Attitude on 21-st century skills is 50.4%; ii) STEM Attitude has a positive and significant effect on computational thinking (H2). This is indicated by the p-value (0.000) <0.05 and the path coefficients value is positive (0.680). while the value of the correlation coefficient (R-square=0.462) means that the effect of STEM Attitude on 21-st century skills is 46.2%; iii) Computational thinking has a positive and significant effect on 21-st century skills (H3). This is indicated by the p-value (0.000) <0.05 and the path coefficients value is positive (0.427). The path coefficients and significance are presented in Figure 2.

The research findings show a positive and significant effect between STEM Attitude on computational thinking skills and 21st-century skills in vocational school students. This underscores the importance of learning designed using a STEM approach to train and develop computational thinking and 21st-century skills [36]–[38]. Through STEM-based learning activities, educators will guide students through meaningful projects and learning environments because computational thinking skills cannot develop by themselves but through a learning and mentoring process [39].

In terms of learning design, STEM-based learning models such as project-based learning, problem based learning always give positive results in increasing computational thinking skills and 21st-century skills [40]–[42]. While in terms of subject matter, there are several appropriate materials to teach the concept of computational thinking, including coding, programming, games, and other computer applications [43]. However, although the concept of computational thinking skills is based on computer science, these skills can also be developed through other lessons [44].

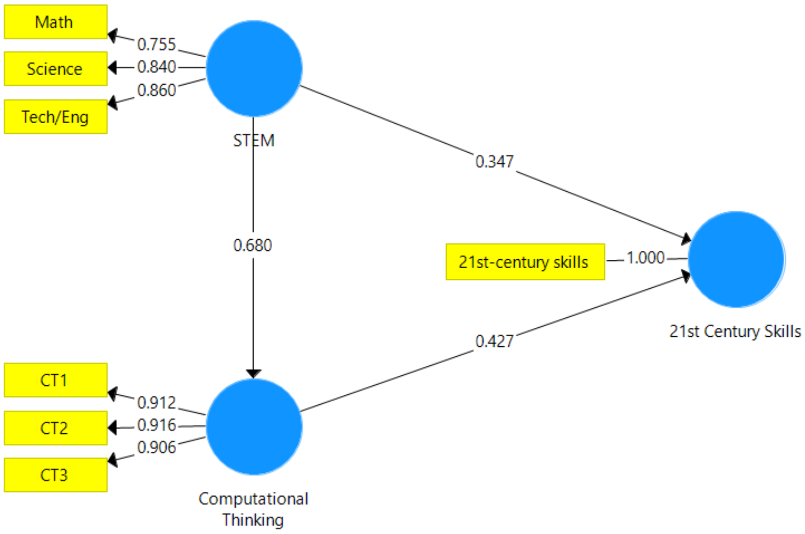


Figure 2. Path coefficients and significance

In the vocational school curriculum, The Royal Society states that computational thinking is a skill that must be the main focus so that the curriculum developed is based on the development of these skills. This is because computational thinking skills are very important for students, especially vocational schools [45]. Students who have good computational thinking skills will make them smarter, understand technology faster, make students' learning attitudes more optimistic, have the ability to overcome open problems, have perseverance in working through challenges, have resilience in dealing with complex problems, and be able to improve higher-order thinking skills [46], [47].

In addition, computational thinking skills can also stimulate other skills, such as creative thinking skills, critical thinking and cooperative work, which are part of 21st-century skills [48]–[52]. This means a linear relationship between computational thinking skills and 21st-century skills. On the other hand, the better one's computational thinking skills, the better 21st-century skills. This is by other findings in this study, namely that students' computational thinking skills positively and significantly affect 21st-century skills.

## 4. CONCLUSION

The results of this study fill the gap from the limitations of previous research related to STEM attitudes, computational thinking and their influence on 21st-century skills. This study found that STEM Attitudes had a positive and significant effect on computational thinking skills and 21st-century skills. Further findings, computational thinking skills have a positive and significant effect on 21st-century skills.

Indonesia as a whole suffers from a lack of STEM programs available to students which results in a lack of STEM professionals in the younger generation and, thus, undermines our ability to compete with other developed countries on a global scale. The results of this study provide additional evidence that STEM has a positive impact on improving computational thinking and 21st-century skills. Governments and the education community should collaboratively encourage schools to develop and practice STEM learning aimed to develop 21st-century skills and computational thinking, particularly in vocational schools. This collaborative role is needed in efforts to promote STEM education, such as training teachers in STEM education and providing STEM learning guides.

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