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Structural model of information and communication technology and 21st-century skills in vocational school students

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Abstract

The digital era has pushed the learning process to use ICT and promote critical thinking, communication, collaboration, and creative thinking skills in students (4C skills). The research on the effect of ICT skills on the critical thinking, communication, collaboration, and creative thinking skills of students (4C skills) has been partially conducted. However, comprehensive insight should be provided. The research aims to investigate how ICT skills may affect the critical thinking, communication, collaboration, and creative thinking skills of students. The research was conducted using a structural equation model with 507 students as the sample. The measurement model indicates that the indicators and constructs are valid and reliable. The structural model shows that ICT skills have positive effects on critical thinking skills. ICT skills have also shown positive and significant effects on students' communication and collaboration skills. In addition, ICT may also increase students' creativity. The research results can be basic for teaching and learning practices that might promote students' 4C skills.

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1. Introduction

The learning process in the digital era has been pushed to use information and communication technology (ICT) (Rahmatullah et al., 2022). ICT usage in education is disrupted by the COVID-19 pandemic. Governments of some countries implement school closure policies in order to limit the spread of the pandemic (Ali, 2020; WHO, 2020). The learning process has been transformed from a classroom into a virtual room using online meeting applications such as Zoom (Adam Stefanile, 2020). However, the use of ICT to achieve an effective distance learning process must be accompanied by students' and teachers' (Adam Stefanile, 2020).

To fulfill their function of preparing students to be part of society, schools should prepare their environments for students to acquire 21st-century skills (Almerich et al., 2020). The skills include communication, collaboration, critical thinking, and creativity skills. The preparations are in the form of a curriculum (Erstad & Voogt, 2018), programs (McMahon, 2009), learning model (Isnaeni et al., 2021), or media (Mahande & Malago, 2021; Stolaki & Economides, 2018). The preparations, however, should be done using ICT. The connection between utilizing ICT in the learning process and how to encourage communication, collaboration, critical thinking, and creativity skills should be examined. The use of ICT can be enabled by students' ICT skills.

Prior research has been conducted to investigate the relationship between ICT and critical thinking skills (González-González & Jiménez-Zarco, 2015; McMahon, 2009), ICT and communication skills (Isnaeni et al., 2021; José Sá & Serpa, 2018; Judge et al., 2011; María A et al., 2018), ICT and collaboration skills (Blau et al., 2020; Dewi & Muhid, 2021; Gellerstedt et al., 2018), and between ICT and creativity (Henriksen et al., 2018; Nikolopoulou, 2018; Stolaki & Economides, 2018). However, this prior research examined the relationship between ICT skills and a particular part of 4C skills. There has been no research conducted to empirically investigate the relationship between ICT skills, critical thinking, collaboration, communication, and creativity skills.

Comprehensive understanding on ICT utilization and skills relationship with 4C skills can serve as the foundation for further development of strategies, models, techniques, and media used in the learning process to develop students' 4C skills. The development of strategies, models, techniques, and media within a strong theoretical framework will effectively increase students' skills.

1.1. Related Studies

There have been several previous studies about 21st-century skills. In research investigating the relationship between factors of 4C, Guo (2017) stated that creativity is developed through critical thinking facilitated by collaboration and communication skills. The research used literature to build a framework of 21st-century skills in the learning process. However, the framework does not include ICT skills.

González-González & Jiménez-Zarco (2015) conducted research to investigate how students' critical thinking may be developed through virtual learning. The study was carried out in an open university using audio-visual media. The findings suggest that the media encourages students' critical thinking. In addition, another study conducted by Isnaeni et al. (2021) also examines the effects of the ICT-oriented model on students' critical thinking. The result is consistent with previous research, which indicates that the use of ICT may promote the critical thinking of the students. Research by Isnaeni et al. (2021) also measures the ICT effect on students' communication skills. The result shows that the ICT-oriented model increases students' communication skills.

Dewi & Muhid (2021) and Blau et al. (2020) conducted similar research on the effect of ICT on the collaborative skills of the students. Both studies conduct collaborative learning using ICT. The results of the studies indicate that using ICT increases students' collaborative skills. In addition to other skills, the

ICT effect on creativity has also been investigated (Henriksen et al., 2018). The research was conducted using a literature review. The result shows that technology and creativity are related.

1.2. The Purpose of the Study

This research aims to investigate the relationship between ICT and 4C skills based on Guo's model. The purpose of the study is to answer the following questions:

1. How does ICT affect critical thinking skills?
2. How does ICT affect communication skills?
3. How does ICT affect collaboration skills?
4. How does ICT affect creativity skills?

2. Methods

The relationship between latent variables and their indicators will be assessed using a structural equation model with the partial least squares method (PLS-SEM). PLS-SEM is employed since it is a multivariate model that might be used to explain a complex model and the relationships between variables in the model (Akter et al., 2017). PLS-SEM can also explain the theory and give recommendations on learning and teaching practices (Joe F. Hair Jr. et al., 2017). The connection between latent variables and their nodes will be written in reflective form. In reflective form, nodes become indicators of the causality of the variable (Hanafiah, 2020). Since the construct is composite, PLS-SEM may give a small bias for parameter estimation (Sarstedt et al., 2016).

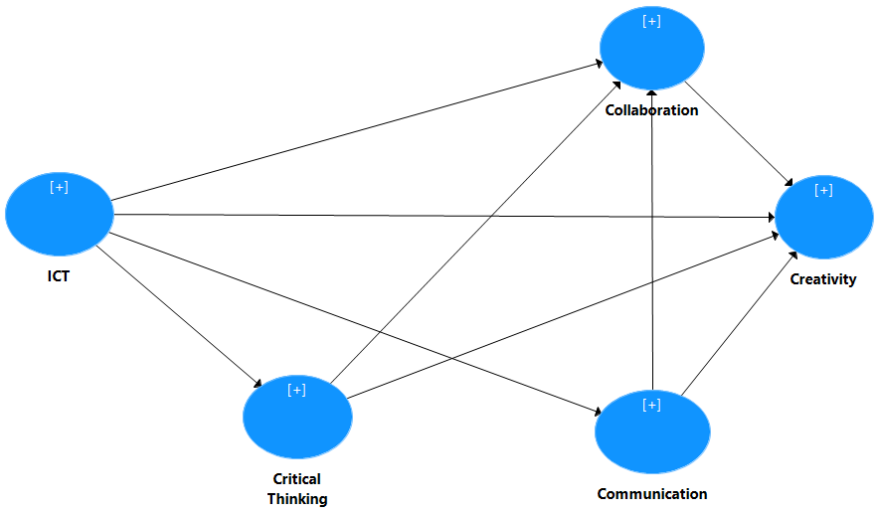

Figure 1. Framework of ICT's impact on 4C

The evaluation of the structural equation model lies in two consecutive parts. The first part is the measurement model, and the second one is the structural model (Joe F. Hair Jr. et al., 2017; Hanafiah, 2020). Paths between variables are constructed based on Guo's model (2017), which connects critical thinking, collaboration, communication, and creativity. The model is expanded by including ICT as an endogenous variable that may influence all parts of 4C.

2.1. Instruments

The indicators are developed from theory related to the latent variables. Each construct is reflected by 4 items.

Table 1. Constructs and Their Indicators

Constructs	Indicators	Source
ICT skill	Managing information and media	(UNESCO Bangkok, 2015)
	Computer usage	
	Other information technology usage	
Communication Skills	Effective written communication skill	(Lemke, 2002)
	Effective oral communication skill	
Collaboration Skills	Virtual collaboration skill	(Fisher, 2010; Khan & Forshaw, 2017)
	Physical collaboration skill	
Critical Thinking Skills	Critical thinking	(Lai & Viering, 2012; Saavedra & Opfer, 2012)
	Problem solving skill	
Creative Thinking Skills	Solving complex problem	((OECD), 2018)
	Creating new thing or idea	

The data of variables are gathered using a questionnaire. *Questionnaire* is a research instrument that might be used to gather quantifiable data rapidly (Radhakrishna, 2007). The response to each statement on the questionnaire is on 5 scale Likert ranging from 1 (totally disagree) to 5 (strongly agree).

2.2. Sample

To get unbiased results, the number of samples should exceed the minimum number of samples. In the structural equation model, the number of minimum samples is based on the count of indicators or nodes. The rule of thumb for the minimum sample in PLS-SEM is 10 times the number of nodes (Joseph F. Hair et al., 2021). There are 20 nodes in the models, which means that the minimum sample is 200. The research includes 507 high school students, which means it is an adequate number of samples.

3. Results

3.1. Measurement Model

The measurement model, often called “the outer model,” aims to check the reliability and validity of the constructs and their indicators (Lin et al., 2020). Assessment of the measurement model includes reliability and validity checks of items and constructs. These measures are the first step to be taken to examine the relationships between constructs. The indicators should represent their construct, which can be reflected through these measures (Sarstedt et al., 2022). Assessment of the measurement model consists of four steps: (1) reliability check of indicators, (2) internal consistency reliability check, (3) validity of convergent, and (4) validity of discriminant (Joe F. Hair et al., 2011, 2012; Joseph F. Hair et al., 2019).

Table 2. Reliability and Convergent Validity of the Construct

Constructs	**Nodes**	**Loadings**	**Composite Reliability**	**AVE**
ICT Skills	LICT1	0.73	0.817	0.527
	LICT2	0.708		
	LICT3	0.735		
	LICT4	0.731		
Critical Thinking Skills	LCRI1	Out	0.817	0.691

	LCRI2	Out		
	LCRI3	0.836		
	LCRI4	0.827		
Collaboration Skills	LCOL1	Out	0.766	0.53
	LCOL2	0.555		
	LCOL3	0.867		
	LCOL4	0.728		
Communication Skills	LCOM1	0.875	0.835	0.717
	LCOM2	Out		
	LCOM3	Out		
	LCOM4	0.817		
Creativity Skills	LCRE1	Out	0.827	0.615
	LCRE2	0.83		
	LCRE3	0.798		
	LCRE4	0.721		

*) Items marked "Out" has factor loadings less than 0.4

The indicator's reliability can be assessed through its factor loadings. A good factor loading should be at least 0.708, which means that the indicator reflects 50% of its construct variance (Joseph F. Hair Jr. et al., 2021). However, items with loadings above 0.4 should be maintained in the model (Joseph F. Hair Jr. et al., 2021; Hulland, 1999). The result shows that some indicators should be excluded from the model because of their low reliability: (1) LCRI1, (2) LCRI2, (3) LCOL1, (4) LCOM2, (5) LCOM3, and (6) LCRE1.

The popular metric to measure the construct's reliability is Cronbach's alpha. However, this metric is shown to be more conservative than composite reliability (Sarstedt et al., 2022). Composite reliability is regarded as a more accurate reliability metric than Cronbach's alpha (Joe F. Hair et al., 2020). The composite reliability of the constructs is shown to be more than 0.708, which means that the indicators, all together, reflect a minimum of 50% of the construct variances (Joe F. Hair et al., 2020; Jörg Henseler et al., 2015; Nitzl et al., 2016). The next metric to be evaluated is the average variance extracted (AVE). AVE indicates the variances reflected by the indicators of their construct and the discriminant validity (do Valle & Assaker, 2016). The rule of thumb for this metric is 0.500, which means that at least 50% of the construct variance is shared with its indicators. The four constructs in this research show an AVE greater than 0.500, which means that they have adequate convergent validity.

Table 3. Hetero-Trait Mono-Trait Ratio of the Construct

	ICT	Critical Thinking	Collaboration	Communication
ICT				
Critical Thinking	**0.528**			
Collaboration	0.581	**0.841**		
Communication	0.624	0.828	**0.856**	
Creativity	0.679	0.801	0.884	**0.895**

The next step will be the discriminant validity evaluation. There are 3 metrics that can be used to evaluate this validity type: (1) fornell-larcker criterion, (2) cross-loadings, and (3) heterotrait monotrait

ratio (Hanafiah, 2020). However, HTMT has the most precise and comprehensive measure among them (Joe F. Hair Jr. et al., 2017; Voorhees et al., 2016). HTMT indicates the ratio of the correlation between constructs and within items in the construct (Voorhees et al., 2016). The ratio is equal to 1, and the two constructs are similar. It makes the ratio have an upper bound of 0.85 as a rule of thumb (Jörg Henseler et al., 2015). HTMT ratio between constructs in the model has a value of less than 0.85 except for communication-collaboration and communication-creativity. However, this HTMT ratio of 0.9 is acceptable for relatively similar constructs (Sarstedt et al., 2022).

The results of the measurement model indicate that indicators and constructs are valid and reliable. It means that the model can be used to investigate its structural characteristics.

3.2. Structural Model

The structural model investigates the size and significance of the paths between constructs of the model (Joe F. Hair Jr. et al., 2017; Jorg Henseler, 2021). These investigations will be begun by conducting a bootstrap. Bootstrap is a resampled method for gaining needed statistics. The bootstrap will be conducted with 10,000 replications as the recommended number of replications in the structural model (Streukens & Leroi-Werelds, 2016). There are 3 types of effects in path analysis: (1) direct effect, (2) indirect effect, and (3) total effect (Nitzl et al., 2016). However, the total effect has a more comprehensive picture of paths in the structural model (Joseph F. Hair et al., 2021; Nitzl et al., 2016). The total effect of the construct will be stated in the form of a confidence interval, giving more information about the parameter estimated (Ringle et al., 2012).

Table 4. Total Effect of Constructs

Path	Total Effect	Conf. Interval	
		2.50%	97.50%
ICT -> Collaboration	0.375	0.295	0.453
ICT -> Communication	0.431	0.354	0.507
ICT -> Creativity	0.489	0.411	0.569
ICT -> Critical Thinking	0.347	0.268	0.428
Critical Thinking -> Collaboration	0.285	0.191	0.381
Critical Thinking -> Creativity	0.231	0.133	0.33
Communication -> Collaboration	0.312	0.2	0.424
Communication -> Creativity	0.361	0.26	0.459
Collaboration -> Creativity	0.262	0.166	0.358

The bootstrapping result shows that all paths on the model have a significant total effect (Table 4). ICT skills have positive significant total effects on Collaboration ($\beta = 0.375, CI[0.295,0.453]$), Communication ($\beta = 0.431, CI[0.354,0.507]$), Critical Thinking ($\beta = 0.347, CI[0.268,0.428]$), and Creativity ($\beta = 0.489, CI[0.411,0.569]$) skills. Similarly, Critical thinking has positive significant total effect on Collaboration ($\beta = 0.285, CI[0.191,0.381]$) and Creativity ($\beta = 0.231, CI[0.133,0.330]$) skills. Moreover, communication skills have significant total effects with positive signs on Collaboration ($\beta = 0.312, CI[0.200,0.424]$) and Creativity ($\beta = 0.361, CI[0.260,0.459]$) skills. In addition, students' ability to collaborate has a positive significant total effect on creativity skills ($\beta = 0.262, CI[0.166,0.358]$).

4. Discussions

The present research examines the relationship between ICT, critical thinking, collaboration, communication, and creative thinking skills. The structural model of these variables was investigated to check the relationships between constructs.

ICT and Critical Thinking Skills

The results indicate that students' ICT skills have positive impacts on their critical thinking skills. This result is consistent with previous studies (González-González & Jiménez-Zarco, 2015; McMahon, 2009). However, critical thinking may also have less correlation with ICT skills (Valtonen et al., 2017). The impact of students' ICT skills on critical thinking may come from the fact that critical thinking skills must be possessed by students in this digital era (Penkauskienė et al., 2019). They should use their critical thinking skills to distinguish the quality of the information they get in society.

Schools are the place where students prepare themselves to be part of society. This task forces the school to adapt to the challenges that students face in society. Awareness of this issue of information quality can lead schools to improve their use of ICT to encourage critical thinking in their students (Almerich et al., 2020).

ICT and Communication Skills

The data indicates that students' ICT skills have increased their communication skills. This result is in line with prior research (Isnaeni et al., 2021; José Sá & Serpa, 2018; Judge et al., 2011; María A et al., 2018). The use of ICT in the learning process among Indonesian students includes e-learning. There are three elements of e-learning: (1) the technological aspect; (2) the accessibility of resources; and (3) the communication-oriented aspect (Arkorful & Abaidoo, 2015; Guri-Rosenblit & Gros, 2011). The third part of the e-learning elements may promote students' communication skills. The communication-oriented element emphasizes e-learning as communication, interaction, and collaboration tools.

The use of ICT in the learning process can enhance student-teacher and student-student interaction, leading to the development of communication skills.

ICT and Collaboration Skills

The analysis shows that students' ICT skills have a positive impact on their collaborative skills. This research has similar findings to previous research (Blau et al., 2020; Das, 2019; Dewi & Muhid, 2021; Gellerstedt et al., 2018). ICT skills may relate to ICT utilization in information sharing and decision-making for a group of students (Wang, 2010). Utilizing ICT in the classroom may engage students in the learning process and motivate them to continuously exchange ideas with their peers (Al-Azawei, 2019). Teachers using ICT in the learning process emphasize collaborative activities (Valtonen et al., 2017). This case is also applied in Indonesian schools since the new K13 curriculum is used. The curriculum asks teachers to use ICT intensively, dividing students into groups to discuss the learning material. In this way, ICT skills of students may influence their collaboration skills.

ICT Skills and Creative Thinking Skills

The results show that students' ICT skills have impacted their creativity skills. This finding is related to previous research (Henriksen et al., 2018; Nikolopoulou, 2018; Stolaki & Economides, 2018). The use of ICT allows students to develop, create, and realize their ideas (Loveless, 2007). ICT skills lead students to generate new ideas or find a new way to look at familiar ideas. They can also transform their idea into a product with the help of their ICT skills.

Creativity within an ICT environment can be gained by using ICT features to support creative processes. To obtain the functionality, students and teachers must have extensive experience and familiarity with ICT in the learning process. The experiences will make students and teachers understand the role of ICT in their creative practices.

5. Conclusions

A positive effect of ICT skills has been found on critical thinking, communication, collaboration, and creativity skills (4C skills). Thus, an increase in ICT skills may also increase 4C skills. The ICT skills may give the students a chance to improve their communication and collaboration skills, which will lead to their critical thinking being transformed into creativity skills. The fact that ICT skills may affect these skills supports the argument of Erstad & Voogt (2018), who stated that ICT skills are related to other 21st-century skills.

This study is conducted with limitations. The students are not randomly chosen, which might affect the parameter estimation result. This should be considered in future research. A replication of the research with randomly taken samples will be necessary to get a better result.

6. Recommendations

The research can be used to strengthen the frameworks in the vocational high school learning process, particularly those that use ICT. Some of the limitations and directions for the future are now addressed. Further work on 21st-century skills should also address the effects of some additional variables. Gender and educational level may give further insight into the models. The instruments used should also be expanded to include a deeper representation of skill subcomponents. This will lead to a better explanation of the relationship between skills.

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