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Enhancing Higher-Order Thinking Skills on Mathematics Students by TPACK Concepts in Digital Era

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Abstract
Learning success in the era of technology and the industrial revolution 4.0 (R.I. 4.0) necessitates higher-order thinking skills and TPACK among students. However, in students learning activities, when they are required to think critically and creatively but still find it difficult to apply high levels of technology. As a result, if students' TPACK skills are lacking, they will not be able to acquire higher-order thinking skills. It is one of the situations that lead to failure in learning mathematics these days. This study aimed to investigate the relationship between TPACK and higher-order thinking skills and include it into a structural model of TPACK and higher-order thinking skills students in online mathematics learning. It is the cross-sectional quantitative research that employed the structural equation model analysis. The number of samples used in this study was the amount of 279 students in Universitas Muhammadiyah Purwokerto and Universitas Riau. The finding of this study was yielded confirmatory factor analysis models for higher-order thinking skills and TPACK with three factors and seven factors. While the structural model shows that the relationship between higher-order thinking skills and TPACK is in a high score ($\beta = 0.912$). Therefore, the findings of this study lead to alternative ways of thinking about mathematics that will maximize TPACK and higher-order thinking skills, hence improving the quality of mathematics learning at the high education level.
Keywords: Higher-order Thinking Skills, TPACK, Mathematics Learning, Structural Equation Model.

Introduction

The term "Industrial Revolution 4.0" has been bandied about in recent years. The omnipresent internet network, artificial intelligence, and machine studies were all hallmarks of the Fourth Industrial Revolution (Patil et al., 2019). The Internet of Things (*IoT*) refers to the use of the internet network in all aspects of life. Online transportation, e-commerce, and e-learning are examples of modern *IoT* network uses (Naismith et al., 2016). The *IoT* is a network that is made up of numerous networks (Mashrah, 2017). When the *IoT* network is combined with user mobility technology and data analysis, it creates a new educational paradigm (Traxler, 2019). The new paradigm in question is education that is aided by the use of technology.

Furthermore, according to Warner and Kaur (2017), learning success in the era of technology and the industrial revolution 4.0 (R.I. 4.0) necessitates critical and creative thinking skills among students. To develop comprehension and meet the necessities of today's life, thinking must be mastered. As a result, higher-order thinking skills becomes a space where students can think critically and creatively. In the process of analyzing, evaluating, and making in the form of providing an assessment of a fact being studied or being able to create from something that has been studied creatively, higher-order thinking skills indicates that students can combine facts and ideas in the process of analyzing, evaluating, and making. According to Maker, Jo, and Muammar (2008), higher-order thinking skills is a learning process in which students are required to manipulate information and ideas in certain ways to gain new understanding and implications.

Three assumptions about thinking and learning are central to the higher-order thinking skills approach. To begin with, the levels of thinking and learning are inextricably linked and interrelated. Second, thinking is linked to the content of subject matter in real life, which aids in the acquisition of higher-order thinking skills abilities. Third, higher-order thinking skills entail a variety of thought processes that are applied to circumstances that are complex and have a lot of variables (Wulan, 2017).

The five steps of the thought process that can be utilized in classroom learning are used to identify higher-order thinking skills. The five steps are as follows: (1) developing a learning formula that propels pupils to higher levels, and (2) asking questions (3) practicing before the evaluation; the level of student thinking is directly proportional to the level of questions presented. Selecting learning activities that allow students to practice will encourage them to think critically, examine, filter, and improve their learning, and provide feedback and assessment of their progress (Thomson, 2019).

When students are required to think critically and creatively but still find it difficult to apply high levels of technology, one of the situations that lead to failure of learning mathematics during the COVID-19 pandemic is when they are required to think critically and creatively but still find it difficult to apply high levels of technology. Both TPACK and higher-order thinking skills require extra attention when done online. As a result, if students' TPACK skills are lacking, they will not be able to acquire higher-order thinking skills. According to prior research by Birel et al (2018), 11.35 percent of students in the Mathematics for Industry class still struggle to communicate their higher-order thinking skills. This is due to their lack of understanding of ideas and TPACK. Furthermore, Saedah (2019) discovered that 16.33 percent of students at the University of North Sumatra's Faculty of Education had difficulty accepting higher-order thinking skills since their critical and creative thinking skills were not optimized. Another study, Eynde and Corte (2020) found that 15-20 percent of students in the United States exhibit lower-than-optimal higher-order thinking skills when not supported by TPACK in the application of online mode learning.

In other words, two components, TPACK, and higher-order thinking skills can be used to explain the success of a student's mathematics learning during the COVID-19 pandemic. TPACK also aids in the creation of favourable learning environments by acting as a tool for simplifying and expediting the process of understanding mathematics while learning and offering skills in the use of technology (Booker, 2017). Furthermore, higher-order thinking skills indicate that students can connect, alter, and change their knowledge and experience to think critically and creatively about mathematics to make judgments and solve problems in novel settings (Schlesinger & Wang, 2019).

The researcher finds that the fulfilment of low TPACK in online learning is challenging to achieve optimally based on many research findings. As a result, achieving higher-order thinking skills in students' learning processes might be challenging. This emphasizes the need for intervention and assesses the extent to which these three criteria aid pupils in overcoming this issue.

On the other way, the structural model's construction is important because it can help researchers answer questions like "how can students succeed in online mathematics learning during the COVID-19 pandemic emergency?" and "Are there any contributing factors to TPACK and higher-order thinking skills in online mathematics learning during the COVID-19 pandemic emergency?". The construct of this model has current significance for online learning education. As a result, the goal of this study is to look into the relationship between TPACK and higher-order thinking skills and include it into a structural model of TPACK and higher-order thinking skills students in online mathematics learning in the digital age.

Method

This research involves structural equation model analysis. The Structural Equation Model (SEM) is a combination of two statistical principles, namely the notion of factor analysis contained in the measurement model and the concept of regression through a structural model. The measurement model explains the relationship between variables and their indicators while the structural model explains the relationship between variables. The measurement model is a study of psychometrics while the structural model is a study of statistics (Kline, 2017). The structural model in this study describes the link between TPACK and higher-order thinking skills. The relationship can be in the form of correlation or influence. Correlation between variables is expressed by a line with arrows at both ends, while the effect is denoted by an arrow at one end (Byrne, 2019). (Byrne, 2019). The association between TPACK and higher-level learning is seen in figure 1 below.

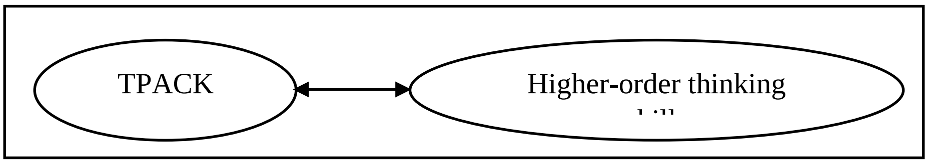

Figure 1. The Principal Relationship Between Constructs

The students of the Universitas Muhammadiyah Purwokerto and Universitas Riau are the study's population demographic. Students in the mathematics education study program in semesters II, IV, VI, and VIII who took online mathematics learning in the COVID-19 pandemic era of 2020/2021 academic year are included in the sample. The sample in this study amounted to 279 students. The research to be undertaken contains four procedures:1) Determine the Measurement Model; 2) Determine the CFA Model of TPACK; 3) Determine the CFA Model of higher-order thinking skills, and 4) Determine the goodness of fit on the structural model.

Result and Discussion

Data Respondents

The number of samples used in this study totaled 279 Universitas Muhammadiyah Purwokerto and Universitas Negeri Riau students. Male students account for 248 students (88.89 percent) of the total, with female students accounting for the remaining 11.11 percent. The remaining students are divided into three groups: 28.67 percent are third-semester students, 103 of the 279 students are fifth-semester students, and 34.41 percent are seventh-semester students. If you look at the student population's geographic distribution, 63.80 percent live in cities and 101 students live in villages. The daily internet access time is divided into three categories: 2 students with less than 3 hours of access, 242 students with 3-5 hours of online access, and 35 students with more than 5 hours of internet access.

Exploratory Factor Analysis

It was discovered employing the analysis that the Kaiser Meyer-Oikin (KMO) values for the items in the TPACK and higher-order thinking skills construct questionnaires had values greater than 0,50 for both. This indicated that the data did not have serious multicollinearity problems and that the items in the constructs could be carried out using a factor analysis method for each construct. The results of Barlett's test of sphericity (see Table 1) revealed a statistically significant value of 0.000 (p 0.05), indicating that the item is suitable for factor analysis.

Table 1. The KMO and Barlett's Test of Sphericity for the constructs

Kaiser-Meyer-Olkin Measure and Barlett's Test of Sphericity		TPACK	Higher-order thinking skills
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.860	.840
Bartlett's Test of Sphericity	Approx. Chi-Square	3845.677	955.250
	df	561	66
	Sig.	.000	.000

Confirmatory Factor Analysis

The Cronbach Alpha reliability criteria are used to get the dependability value for the measurement model in question. Criteria for Composite Reliability (CR), as well as criteria for Average Variance Extracted (AVE). To reach the dependability value, the Cronbach Alpha value must be more than 0.7 ($\alpha > 0.7$), the CR value must be 0.6 or greater than 0.6 (CR > 0.6), and the AVE value must be 0.5 or greater than 0.5 (AVE > 0.5) for each of the constructs. After conducting the CFA TPACK analysis, the following are the final decision values for the CR, the AVE, and the Cronbach Alpha values. Table 2 was the detailed information on final decision values for the CR, the AVE, and the Alpha Cronbach values of TPACK construct.

Table 2. The CFA of TPACK values of CR, AVE and Alpha Cronbach

Constructs	**Item**	**Factor loading**	**CR >0.6**	**AVE > 0.5**	**Alpha Cronbach >0.70**	**Decision**
Content Knowledge	Tpack9	0.673	0.783	0.587	0.893	Achieved
	Tpack12	0.783				
	Tpack15	0.763				
	Tpack22	0.652				
	Tpack23	0.583				
Technological Knowledge	Tpack5	0.783	0.673	0.568	0.876	Achieved
	Tpack6	0.639				
	Tpack17	0.642				
	Tpack21	0.742				
Pedagogical Knowledge	Tpack1	0.674	0.639	0.538	0.863	Achieved
	Tpack2	0.672				
	Tpack3	0.784				
	Tpack4	0.633				
	Tpack27	0.623				
	Tpack29	0.748				
Technological Pedagogical Knowledge	Tpack24	0.632	0.784	0.583	0.786	Achieved
	Tpack25	0.633				
	Tpack26	0.782				
	Tpack33	0.572				
	Tpack34	0.733				
Technological Content Knowledge	Tpack30	0.633	0.644	0.588	0.873	Achieved
	Tpack31	0.632				
	Tpack32	0.783				

Pedagogical Content Knowledge	Tpack14	0.663	0.672	0.673	0.775	Achieved
	Tpack18	0.573				
	Tpack19	0.773				
	Tpack20	0.653				
Technological Pedagigical Content Knowledge	Tpack7	0.667	0.674	0.633	0.733	Achieved
	Tpack8	0.663				
	Tpack10	0.673				
	Tpack11	0.676				

Based on the EFA analysis, TPACK consists of 7 sub-constructs. The Content Knowledge consists of 5 items (Tpack 9, 12, 15, 22, 23), Technological Knowledge consists of 4 items (Tpack 5, 6, 17, 21), Pedagogical Knowledge consists of 7 items (Tpack 1, 2, 3, 4, 27, 28, 29), Technological Pedagogical Knowledge consists of 5 items (Tpack 24, 25, 26, 33, 34), Technological Content Knowledge consists of 4 items (Tpack 16, 30, 31, 32), Pedagogical Content Knowledge consists of 5 items (Tpack 13, 14, 18, 19, 20). And Technological Pedagogical Content Knowledge consists of 4 items (Tpack 7, 8, 10, 11). The CFA analysis was continued to the second analysis because there were eigenvalues that did not meet the requirements (e<0.4). So that some items were omitted, they are Tpack 13 (e = 0.21), Tpack 16 (e = 0.15), and Tpack 28 (e = 0.21). The Figure 2 was the final CFA model of TPACK.

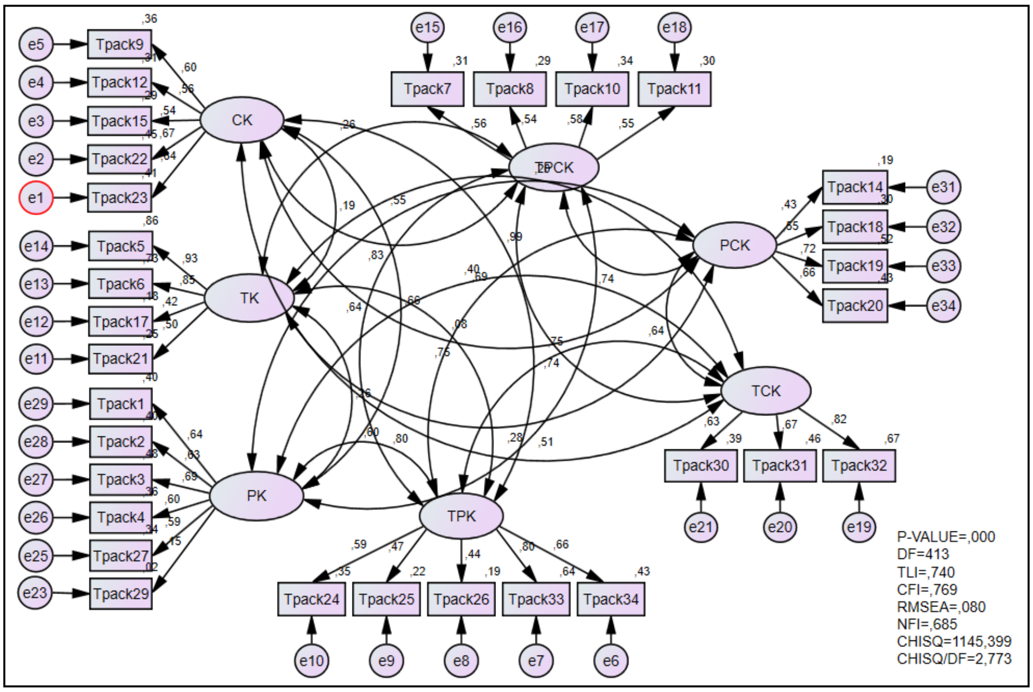

Figure 2. The CFA model of higher-order thinking skills

Meanwhile, on the EFA analysis, the higher-order thinking skills consist of 3 sub-constructs, they are Analyze, Evaluate, and Create. The Analyze consists of 4 items (Plt 1, 2, 3, 4), the Evaluate consists of 4 items (Plt 9, 10, 11, 12), and The Create consists of 4 items (Plt 5, 6, 7, 8). Furthermore, the CFA analysis was continued to the second analysis, since there were eigenvalues that did not meet the requirements (e<0.4). So one item is omitted: Plt 3 (e = 0.34). The final CFA model of higher-order thinking skills is shown in Figure 3 below.

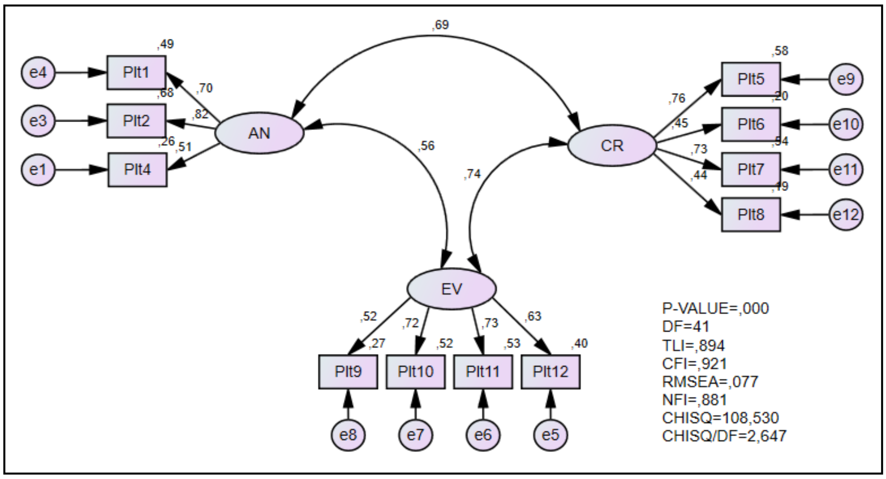

Figure 3. The CFA Model of higher-order thinking skills

Subsequently, the analysis was continued to seek the CR, AVE, and Cronbach Alpha values from the CFA of higher-order thinking skills (See Table 3).

Table 3. The CFA of TPACK values of CR, AVE and Alpha Cronbach

Constructs	**Item**	**Factor loading**	**CR >0.6**	**AVE > 0.5**	**Alpha Cronbach >0.70**	**Decision**
Analyze	Plt 1	0.887	0.633	0.664	0.779	Achieved
	Plt 2	0.784				
	Plt 4	0.67				
Evaluate	Plt 9	0.674	0.783	0.539	0.897	Achieved
	Plt 10	0.776				
	Plt 11	0.762				
	Plt 12	0.663				
Create	Plt 5	0.876	0.794	0.673	0.887	Achieved
	Plt 6	0.766				
	Plt 7	0.688				
	Plt 8	0.632				

Structural Equation Model

There are three requirements for validation and SEM reliability: unidimensionality, validity, and reliability. The implementation of a pooled CFA prior to the analysis of the structural model is required to meet these three criteria. Achieving uniformity in dimensions can be accomplished by ensuring that the loading factor of each item and dimension is greater than 0.6. In this EFA study, the validity that may be found is comprised of three forms of validity: convergent validity, construct validity, and discriminatory validity. Convergent validity is attained if all items in the measurement model have a statistically significant value or can be verified using the Average Variance Extracted (AVE) value as a measure of reliability. In addition, construct validity was attained based on the value of the fit indicator (goodness-of-fit/GOF), and discriminatory validity was established when the measurement model was devoid of items measuring the same two things as the construct validity item. The validity of discrimination is also obtained if the correlation value for the relationship between two exogenous constructs is less than 0.4, in addition to the other conditions (Tabachnick & Fidell, 2014). The final model of SEM as described in Figure 4.

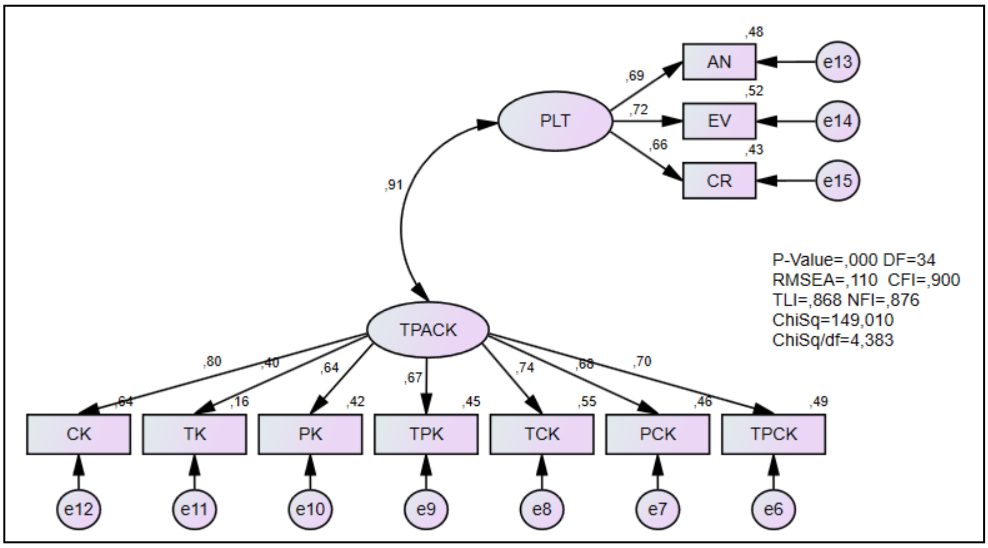

Figure 4. The Structural Model of TPACK and Higher-order thinking skills

Based on the findings of the analysis of the SEM model, the second round of analysis was conducted to determine which SEM model was the most appropriate. The results of all of the relationships between the two constructs are displayed in the following Table 4.

Table 4. The SEM Analyzing of TPACK and Higher-order thinking skills

Sub-constructs			β	SE	CR	p	Decision
AN	←	PLT	0.692	0.484	1.909	0.056	Significance
EV	←	PLT	0.723	0.522	2.430	***	Significance
CR	←	PLT	0.663	0.431	3.401	0.004	Significance
CK	←	TPACK	0.793	0.644	0.498	0.618	Significance
TK	←	TPACK	0.402	0.164	2.529	0.011	Significance
PK	←	TPACK	0.644	0.421	2.434	0.015	Significance
TPK	←	TPACK	0.672	0.452	3.099	0.002	Significance
TCK	←	TPACK	0.743	0.550	3.097	0.002	Significance
PCK	←	TPACK	0.683	0.462	2.409	0.042	Significance
TPCK	←	TPACK	0.703	0.492	3.915	***	Significance

For the sake of this discussion, the value of the relationship can be divided into three stages: the small relationship stage for values less than 0.10, the simple relationship stage for values between 0.10 and 0.50, and the high connection stage for values larger than 0.50.

(Cohen, Manion, & Morrison, 2013). The level of the link was modest (0.010), and the negative was deemed inconsequential by the researchers. Based on the results of the SEM analysis, a strong connection with a value more than 0.50 (β = 0.912) was discovered.

Conclusion

The findings of this study provide information on the current status of the TPACK stage, as well as higher-order thinking skills for mathematics education students at Universitas Muhamamdiyah Purwokerto and Universitas Negeri Riau, based on their responses. The findings of this study may lead to alternative ways of thinking about mathematics that will maximize TPACK and higher-order thinking skills, hence improving the quality of mathematics learning at the high education level. Furthermore, additional research is required to acquire more benefits and the most up-to-date discoveries from aspects that influence learning achievement throughout the Covid-19 epidemic.

The development of the world of education continues to take place in response to the demands of human life and to keep up with the advancement of science and technology, which is becoming increasingly sophisticated and advanced each year. It is also necessary for the world of education to be sensitive to even the smallest changes and advancements in the world of scientific and technological advancement. The job of the instructor is not insignificant in this situation. It is necessary for lecturers or teachers, who serve as the spearhead of education implementation, to continue to expand their knowledge, abilities, and skills.

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