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Relationship of TPACK, motivation, self-regulation, and learning performance on preservice primary school teachers

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ABSTRACT

Technological development could enable pre-service teachers to adopt web design with strong pedagogy, however adaptation requires still unclear an explicit exploration of the factors. This study aimed to identify the effect of technological pedagogical content knowledge (TPACK) on motivation, self-regulation, and learning achievement. It surveyed 406 pre-service teachers from 12 higher education institutions in Indonesia. Data validity and reliability were checked using an exploratory factor, confirmatory, and part analyses. The partial least squares structural equation modelling (PLS-SEM) results showed that TPACK has the most significant role in learning motivation. The result shows that technology integration knowledge also significantly affects self-regulated learning (SRL). In addition, pre-service teachers' TPACK supports their learning motivation to use the web, as well as their academic achievement. Moreover, most students' achievements were constructed by TPACK, learning motivation, and self-regulation. This study implies that the instructor should clarify the project mission and the inquiry system activities in the educational technology course.

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1. INTRODUCTION

Web 2.0 has become a leading tool for use by higher education institutions in learning, specifically during and after the COVID-19 pandemic [1], [2]. It provides content, supports media, and serves as a learning management system (LMS). The Web is commonly used in higher education to deliver constructivist learning activities [3]. Moreover, the LMS role could be set by an admin to support pre-service teacher flexibility in integrating technology into learning [4]. This activity could be evaluated by comparing existing tools in LMS, resources, text, audiovisual media, assignments, tests, video conferences, and forums [5]. The integration is capable of enhancing motivation and the use of self-regulated learning (SRL) for pre-service teachers through web adoption for teaching and learning [6], [7]. However, this exploration requires in-depth evidence of the relationship separately or concurrently. The exploration should show whether the pre-service teachers' learning performance could be seen from the integration's transformation activities. This would help know how pre-service teachers' competence integrates technology into appropriate pedagogy and content.

Technological pedagogical content knowledge (TPACK) is renowned for its pre-service teachers' competence in integrating technology into learning [8]–[10] proposed that TPACK can be conducted using the learning technology by design method because it has a rich context to create a product. The Web has become a reliable technology for facilitating prospective teachers' participation in design [11], [12]. It also facilitates prospective teachers to design based on personal learning [13]. Nevertheless, few studies examined the effect of web integration on learning [14], [15]. This competency allows pre-service teachers to be motivated in their design [16]–[18] and using SRL [19] in the designed technology. The relationships of design factors also require in-depth exploration for instructors in describing the main components in technology integration courses.

The purpose of this research is to explore the relationship between TPACK, motivation, self-regulated learning, and learning performance. The components of each variable would be tested for validation and reliability. This helps in proving the relationship between the four variables. Using factor analysis and partial least square (PLS) SEM analysis helps in analyzing each variable item so that it can be used in the future.

2. THEORETICAL REVIEW

2.1. Technological pedagogical content knowledge (TPACK)

TPACK is an established framework for integrating technology into learning activities. This concept was proposed by [10] for pedagogical content knowledge (PCK) modernization [20]. According to previous study [20], teachers should have pedagogical knowledge (PK) and content knowledge (CK) in their minds. However, other study [10] considered that PK and CK are insufficient in line with technological developments and added TPACK to the PCK integration. This concept developed with more than 8000 discussions detected on Google Scholar. TPACK's derivatives have also been widely used for various purposes, such as WPACK [14], TPACK.xs [21], TPACK-L [22], and 4D-TPACK [23]. For WPACK, Lee and Tsai [14] intercepted the Web into the PCK concept in the same way as [10] did. This framework is divided into seven components, including web-general, web-communicative, web-pedagogical knowledge, web-content knowledge, and attitudes. Additionally, Lee and Tsai [14] defined WPACK as pre-service teachers' belief in their knowledge on adopting online learning to support learning activities.

WPACK has become a potential framework to support student involvement in learning. Web in WPACK is often associated with Web 2.0 [11], online learning [24], and specific platform, such as LMS [25]. Integrating the Web into learning entails using it to improve self-directed learning, communication, and student activity [11], [12], [26]. Therefore, this is a TPACK from the prospective teachers' experience integrating the Web into learning [27]. Xu *et al.* [13] stated that the LMS should be integrated into the prospective teachers' activities as a personal learning environment. Although the Web has facilitated pre-service teachers in managing learning, this still needs to be proven. It is essential to explore the influence of TPACK, learning motivation (LM), SRL, and integration on prospective teachers' motivation and performance. This may help transform traditional teaching and solve the rigid curriculum practice and assessment, as well as software and hardware disability [12]. Therefore, the proposed hypothesis (H1) was TPACK positively affects students' achievement (SA).

2.2. Learning motivation (LM) and TPACK

Intrinsic motivation is the most significant indicator of learning because it relates positively to learning success and performance [28]. This interest [29] could be improved through several meaningful tasks or utility values [30]. Therefore, integrating technology could increase motivation through meaningful learning assignments [31]–[34]. This assignment directly affects achievement in the LMS [16]. The effect is significant when LMS also provides freedom in adopting web designs according to the desired learning preferences [35]. However, LM is still not explored concerning the increase in the prospective teachers' TPACK [36], [37]. Research by Liu e*t al.* [38] recommended exploring the relationship between teacher knowledge and LM. This may prove that web integration increases the prospective teachers' LM. Some studies only evaluated how students' motivation affects the use of LMS [39], [40]. Therefore, the proposed hypothesis (H2) was LM would positively affect SA.

There is a possibility that motivation affects TPACK competence [36], [37] or that TPACK affects LM [16]–[18]. First, Holland and Piper [36] showed that motivation correlates highly with TPACK. However, other study found that the regression coefficient of TPACK and motivation is small, with $\beta=0.21$ [37]. This influence is moderated by goals, tasks, feedback, and SRL [41]. Second, Fernandes *et al.* [17] proposed TPACK's effect on motivation with a regression coefficient of $\beta=0.56$. Instructors must develop awareness when integrating technology to increase students' emotions and motivation in learning [18]. Although it is necessary to explore both, it is more concerning to the effect of TPACK competence on motivation. The web could be more meaningful in increasing the prospective teachers' LM. Therefore, the proposed hypothesis (H3) was TPACK would positively affect LM.

2.3. Self-regulated learning and TPACK

Zimmerman [42] defined SRL as a process of thinking, attitude, and behavior from self-directed learning to achieve goals. This term became an important topic in 1986 as part of metacognition, motivation, and behavior [43]. Metacognition means self-regulated planning, design, implementation, and self-evaluation in integrating technology into learning. In SRL, metacognition is associated with goal-oriented, tentative, and monitoring processes [44]. Moreover, TPACK is a knowledge aspect highlighted when proposed [10], [45] as metacognitive in SRL. This may be due to service quality factors from technology, pedagogy, and institutions in improving SRL [46], [47]. Broadbent *et al.* [48] suggested to explore how interaction with technology increases the independence of pre-service technicians' SRL. Therefore, the proposed hypothesis (H4) was SRL would positively affect SA.

Various studies showed that motivation increases SRL [19], [47], [49]. It activates students' SRL in constructive learning [50] included in the TPACK-in practice process. The increase is due to commitment, metacognitive, satiation, emotional, and environmental control [19]. Additionally, motivation is a vital SRL factor in integrating technology because motivated students would use it to accomplish complex tasks [6]. This involves giving prospective teachers projects to design planning, technology transformation, implementation, and evaluation. Chen and Jang [51] connected TPACK with the ability to plan, monitor, control, and reflect on SRL's role in technology integration. Therefore, the proposed hypotheses were LM would positively affect SRL (H5) and TPACK would positively affect SRL (H6).

This study aimed to determine the effect of web design on LM, SRL, and learning achievement. Exploration was conducted to determine the factors of each latent variable of the instrument items. The variables were evaluated using correlation and part analyses by testing the hypotheses proposed with the structure shown in Figure 1.

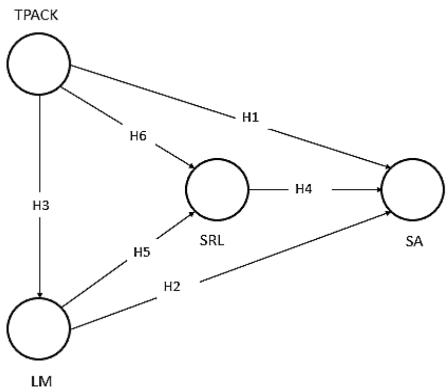

Figure 1. The hypothetic structure model

3. METHOD

3.1. Participants and procedure

A quantitative method with a survey was used to obtain a factor model of the Web design self-efficacy, motivation, SRL, and pre-service teachers' learning achievement. Random sampling was used to select the participants invited to fill out a survey involving 12 higher education teachers from West Java, East Java, and Central Java Provinces, Indonesia. The participants were 406 elementary school teacher candidates selected from 460 teacher candidates. The sample consisted of 49 (12%) male and 357 (87%) female, aged between 18-23, and had been in education for 2-4 years. The teacher candidates programmed educational technology courses in designing lesson plans. Additionally, their universities used LMS in designing learning materials and as a learning add-on.

The survey instrument was distributed online with the teacher's permission. Students filled out a Likert scale (1 to 5) on each question item according to their perception. The survey contained statements about self-efficacy in web design, motivation, SRL, and learning achievement. Furthermore, the responses were selected based on which prospective teacher used the Web to design lesson plans. Missing data were also tested before conducting further analysis.

3.2. Measures

Participants were asked about their names, ages, and years of study. The instrument also asked "yes/no" questions about the Web, such as "Has your college implemented Web learning in its learning technology courses?" Regarding experience in web design, the question asked was "Have you ever designed or developed the Web in a learning technology course?" This ensured that the respondent had conducted a web design before filling out the questionnaire.

Items from the Web design efficacy instrument was developed by modifying self-efficacy in previous technology studies [52]–[54]. It measured the prospective teachers' confidence in adopting the Web as a learning medium. This questionnaire was developed with seven items with a Likert scale of 1-5 from strongly disagree to strongly agree as shown in Table 1. For instance, Wei and Chou [54] modified the statement item, namely "I feel confident about using the Web as an online learning medium." This was analyzed by confirmatory factor analysis (CFA) with a loading factor between 0.78 to 0.85 and the Cronbach's α (reliability) of Web design self-efficacy was 0.90. LM was measured by modifying the motivation and self-regulation toward technology learning (MSRTL) [39], [54]. The measurement focused on why students are interested in the Web as a learning tool. This item was developed using five statements with a Likert scale from strongly disagree=1 to strongly agree=5. For instance, the motivational item developed by [39] is "This Web learning motivates me to study harder because it stimulates my thinking." The CFA results showed the loading factor value ranging from 0.79 to 0.83 and the Cronbach test also indicated a reliable motivation value of 0.88. The item from SRL was modified from [43], [55] to measure self-regulation in Web learning and answered in 4 items. For instance, "I organize learning videos I watch on the Web" was developed from "Will this student volunteer for special tasks, duties, or activities related to coursework?" [43]. Likert scale of 1 to 5 from strongly disagree to strongly agree was selected on the SRL item. The CFA results showed the value of the loading factor ranging from 0.82 to 0.86, with Cronbach's α of 0.86. The students' performance scale was revised from online learning performance [54] with a Likert scale of 1-5 from strongly disagree to strongly agree. This focused on the tasks given to students to achieve learning objectives and the number of statements is eight items. For instance, the item "Web learning assignments increase my knowledge, and my self-development" showed knowledge performance. The loading factor value of students' performance is between 0.77 and 0.83, with Cronbach's α of 0.89.

Table 1. Items of LM, SA, SRL, and web design self-efficacy

Code	Items
Learning motivation	
LM_1	I am motivated when I can complete the tasks given in Web learning
LM_2	I am interested in web learning materials and motivated to learn them
LM_3	I am motivated because this Web learning provides clear guidance on the studied material
LM_4	This Web learning motivates me to study harder because it stimulates my thinking
LM_5	I propose that the lecturer repeat the Web learning according to my needs
Students' achievement	
SA_1	Web learning assignments increase my knowledge and self-development
SA_2	Web learning assignments force me to study
SA_3	Web learning assignments are the primary key to keeping me growing in improving my teaching skills
SA_4	I am very good at finding answers on my own for things that the teacher does not explain in class
SA_5	I answer questions quickly without having to depend on others
SA_8	I can manage my study time with the Web well
Self-regulated learning	
SRL_1	I can log in independently when learning online
SRL_2	I organize the learning videos I watch on the Web
SRL_3	I fill in journals and assignments sent to students on the Web
SRL_4	I am involved in the many questions and replies of each student when learning the Web
Web design self-efficacy	
TPACK_1	I feel confident that I can design online learning through the Web
TPACK_2	I feel confident that I can design various features provided by the application, such as creating blogs, forums, assignments, chats, quizzes, and lessons
TPACK_3	I feel confident that I can create learning materials through the Web with various media, such as typing text, as well as embedding YouTube videos, PowerPoint, and WhatsApp applications on it
TPACK_4	I can adjust the planning in the lesson plan into the learning web design to achieve the learning objectives
TPACK_6	I feel confident asking questions in both oral and written online discussions
TPACK_7	I feel confident using online communication tools, such as Email, WhatsApp, Zoom, and Gmeet, to communicate effectively with others

3.3. Data collection

The lecturer was asked about the technology course that used web learning to ensure the college uses the Web in learning design. Permissions were made to provide information appropriate to their circumstances. Data were collected using a questionnaire with items revised based on their validity and reliability. The questionnaire contained Background information, Web design self-efficacy, LM, SRL, and students' performance. The instrument is transformed into an online form and disseminated through social media groups. The distribution was conducted at the end of odd and even semesters because each university opens educational technology courses differently.

3.4. Data analysis

Survey data were tested using exploratory factor analysis (EFA), confirmatory factor analysis (CFA), correlation, and structural equation modeling (SEM). Initially, Kaiser-Meyer-Olkin (KMO) and Bartlett's tests were applied using SPSS 25.0. The data were then analyzed using EFA to obtain the relevant factors randomly. These factors were determined using CFA according to previous study criteria [56]. EFA and CFA used the principal axis factoring and varimax rotation extraction methods with a high loading factor and a mean commonalities value of 0.70 [57]. The extracted factors were tested for reliability with Cronbach's to determine the internal consistency of each item, at least 0.70. Furthermore, Pearson Correlation was applied to determine the correlation between factors. PLS-SEM was then implemented using SmartPLS 3.2.7. PLS-SEM was used as a factor exploration procedure based on the criteria of the model of fit [58], such as SRMR, Chi-square, and collinearity statistics (VIF).

4. RESULTS

4.1. Exploratory and confirmatory factor analyses

Based on the data from a questionnaire with 5 Likert scales, EFA and CFA were applied with SPSS 25.0 to obtain web design factors on LM, SA, and SRL. Four factors were extracted from the EFA assay and confirmed with CFA as the latent variable. The best extraction results showed the KMO value of 0.96, with $\chi2=7305.352$, $p=0.000$, and the total variance explained together of 67.914%. The loading factor of the four factors ranged from 0.511 to .8, as shown in the rotated component matrix EFA as in Table 2. This indicates that each item shows the latent variable of a strong factor approaching a value of 1 [59].

4.2. Descriptive analysis

The descriptive statistical analysis after adjusting the CFA results from the EFA results is shown in Table 3. Overall, the data indicated that all factors have values exceeding three. SRL had the highest mean value (M=3.6; SD=0.8) and the lowest LM (M=3.31; SD=0.75).

Table 2. Loading factors of LM, SA, SRL, and TPACK

Latent variable	Items code	Component 1	2	3	4	Cronbach's α	CR	AVE
TPACK	TPACK_1	.801	.146	.149	.245	.90	.93	.67
	TPACK_2	.799	.168	.143	.230			
	TPACK_3	.739	.276	.200	.137			
	TPACK_4	.706	.350	.141	.192			
	TPACK_5	.679	.285	.200	.284			
	TPACK_6	.604	.347	.169	.340			
	TPACK_7	.567	.393	.409	.144			
	TPACK_8	.511	.407	.375	.224			
SA	SA_1	.295	.765	.205	.110	.89	.92	.65
	SA_2	.139	.668	.186	.354			
	SA_3	.420	.644	.186	.245			
	SA_4	.353	.625	.338	.254			
	SA_5	.272	.602	.244	.389			
	SA_6	.382	.592	.290	.269			
	SA_7	.383	.515	.297	.328			
SRL	SRL_1	.152	.226	.798	.171	.86	.91	.71
	SRL _2	.145	.149	.783	.317			
	SRL _3	.180	.271	.757	.119			
	SRL_4	.297	.207	.677	.254			
LM	LM_1	.314	.214	.180	.778	.88	.91	.67
	LM_2	.287	.228	.231	.725			
	LM_3	.168	.268	.245	.713			
	LM_4	.385	.376	.304	.522			
	LM_5	.320	.363	.289	.513			

Table 3. Descriptive statistics and correlations between LM, SA, SRL, and web design self-efficacy

Variable	N	Mean	SD
WPACK	406	3.44	.73
SA	406	3.52	.74
SRL	406	3.60	.80
LM	406	3.31	.75

4.3. Reliability and validity of latent variable

It is crucial to test the reliability and validity after obtaining the latent variable from CFA. Table 3 shows the internal consistency reliability and convergent validity. Internal consistency reliability is indicated by Cronbach’s alpha with a value between 0.86 and 0.90. Further references suggest using composite reliability (CR) [60], [61], with a value ranging from 0.91 to 0.93. This value on both criteria includes high-level internal consistency reliability. The latent variable was also evaluated with average variance extracted (AVE) to test convergent validity. All AVE values on all latent variables exceed 0.6, exceeding the threshold of 0.5.

Discriminant validity was also applied, where the quadrat root of AVE should have the largest correlation among the latent variables. Table 4 presents the correlation of Pearson among latent variables and root square AVE in bold values. All variables have a positive and significant relationship (r=0.6, p<0.001). The correlation between LM and SA (r=0.797, p<0.001) was strongest, and weakest between LM with SRL (r=0.602, p<0.001). The results show that the validation discriminant is well established for all latent variables. For instance, the root square’ AVE of LM is 0.821, larger than the correlation of LM with SA (r=0.797), SRL (r=0.602), and TPACK (r=0.728). Similar results are observed for the SA, SRL, and TPACK variables.

Table 4. Fornell-Larcker criterion checking from LM, SA, SRL, and TPACK

Latent variable	Correlation- Fornell-Larcker criterion			
	WPACK	SA	SRL	LM
TPACK	.820			
SA	.775**	.807		
SRL	.640**	.657**	.841	
LM	.728**	.797**	.602**	.821

4.4. Structural equation model of LM, SA, SRL, and TPACK

SEM tests were calculated using PLS Algorithm and maximum iterations: 300 [62], [63]. The SEM-PLS model of this computation is shown in Figure 2. The model’s goodness of fit (GoF) is displayed by the standardized root mean square residual (SRMR) value, which is 0.060. This value is considered suitable because it is less than 0.10 or 0.08 [64]. Additionally, the NFI shows a value of 0.9, corresponding to an acceptable fit close to 1. Figure 2 shows that R-squared measures (R^2) are exposed in numbers that lie in the circle (endogenous latent variable) as regression coefficients. This represents a combined contribution to the latent endogenous variable. For instance, the SA variable is affected by TPACK, LM, and SRL by 71.9%.

The hypothesis was assessed partially between latent variables, LM, SA, SRL, and TPACK, as shown in Table 5. The biggest influence occurs in the WPACK -> LM relationship (β=0.717, t_{H4}=19.671, p=0.000), while the smallest is SRL->SA (β=0.183, t_{H3}=4.348, p=0.000). However, all hypotheses from t_{H1}=19.671 to t_{H6}=4.176 with p=0.000 were accepted. The size effect (f^2) shows a large value for TPACK->LM and TPACK->SA, medium for LM->SA and LM->SRL, and small for SRL->SA and TPACK->SRL [65].

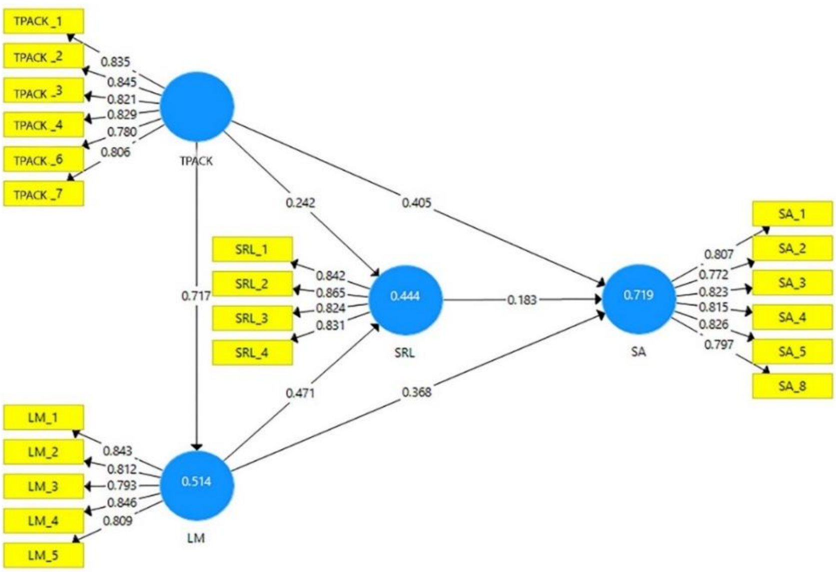

Figure 2. Structural model

Table 5. Hypothesis testing results

Hypothesis	Path	β	t	P	f^2	Decision
H1	TPACK->SA	.406	6.517	.000	.270	Accepted
H2	LM->SA	.368	6.933	.000	.196	Accepted
H3	TPACK->LM	.717	19.671	.000	1.056	Accepted
H4	SRL->SA	.183	4.348	.000	.067	Accepted
H5	LM->SRL	.471	7.555	.000	.194	Accepted
H6	TPACK->SRL	.242	4.176	.000	.051	Accepted

5. DISCUSSION

This study aimed to develop an instrument scale to examine the effect of pre-service teachers' TPACK, LM, SRL, and SA during learning by web design. All latent variables were supported by high Cronbach's Alpha, CR, and EVA to show the reliability of a WPACK effect scale. Also, the validity was represented by a strong loading factor, discriminant validity, and Pearson correlation. This result supports previous studies that built the four constructs [17], [41], [51], probably because the respondents experienced the effect of web adaptation in the course. This validation and reliability might not occur when the respondents could not conduct the Web integration well. The results showed that WPACK related to SA, SRL, and LM when the pre-service teachers integrated the Web into teaching and learning. Therefore, pre-service teachers' motivation should become an essential mediator in influencing SRL and SA. This is represented by the strongest correlation between LM and SA and the weakest between LM and SRL, though the relationship is partial. Therefore, this study explored the factors influencing pre-service teachers when integrating the Web into pedagogical and content courses. The validated instrument could be used to evaluate this factor simultaneously. These results can also have implications that faculties and lecturers can encourage students to organize in the LMS so that they are not left alone to study independently.

The empirical study showed the relationship among pre-service teachers' TPACK, learning interest, self-regulation, learning achievement, and implication of technology integration in courses. SA was formed from TPACK, SRL, and LM by 71.9%. It indicates that student learning achievement is influenced by three main variables. These are prospective teachers' knowledge in web integration, interest in learning to integrate the Web, and ideas, attitudes, and behavior in integration. The results support previous studies on TPACK's role in learning achievement and its relationship with motivation and SRL [17], [51]. Patch analysis also showed that the effect of TPACK on LM was the highest coefficient value, probably because some students are challenged in designing new learning tools. Previous studies found that motivation is important in using the Web to create optimal design activities [3], although anxiety and stress negatively impact technology integration [66]. Therefore, the instructor should create a project that becomes a challenge for prospective teachers. The project should have clear benefits and not be too difficult to complete. Pre-service teachers also should have a basis for completing projects to integrate technology with a clear vision and mission.

TPACK showed a significant effect on SRL with high effect (β=0.242, t=4.176, P=0.000). It indicates that pre-service teachers' TPACK plays a vital role in the idea process, attitude, and behavior of web integration. This supports previous study [46], [51], which showed that a strong technology integration affects pre-service teachers' self-regulation in designing, developing, practicing, and evaluating teaching processes and knowledge. Web knowledge promotes the emergence of thinking in adopting the Web in learning. However, few studies explored the Web's interaction with metacognitive knowledge in integrating technology to determine the pre-service teachers' independence of self-regulation [48]. Technology integration projects could be recommended to develop learning web design ideas, independent adoption process, and self-reported self-control.

6. CONCLUSION

This study focused on the effect of web integration on learning on motivation, self-regulation, and learning achievement, and it help pre-service teachers learn in Web adoption. First, validated instruments could measure TPACK's impact on ideas, motivation, behavior, control, and integration implementation. Second, TPACK significantly influences LM and SRL. This effect is based on how the project is conducted by activating pre-service teachers in challenging situations with clear procedures. Lecturers could be promoted to complete a program to integrate technology into learning with a constructivist approach. The limitations of this study are followed by suggestions for future studies. First, the participants' characteristics are not precise regarding designing the learning Web when taking technology courses at their universities. This requires an in-depth case study to determine how the Web is made flexible in accomplishing project adoption. Further studies could use data collection techniques such as interviewing, observing and documenting pre-service teachers' motivation, SRL, and performance. This study used PLS-SEM to analyze the variance of the covariance in covariance-based SEM (CB-SEM), which emphasizes more detailed assumptions. Therefore, further studies could use other analytical software such as AMOS, LISREL, EQS, and MPlus.

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