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Prospective Elementary Science Teacher in Developing Lesson Plan through Integration of STEM-Based TPACK

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Abstract: This study aims to determine the effect of STEM-integrated TPACK on the ability to plan science lessons and explore the ability of student learning planning in developing self-competencies to become adaptive, professional, creative, and innovative. The research method was a survey with a quantitative approach with 34 even-semester students at the Department of elementary teacher education for the 2021/2022 academic year. Data collection used a questionnaire with a Likert scale and documentation. Data analysis techniques used SEM through AMOS and descriptive analysis. The results show that students are able to implement STEM-integrated TPACK within the 51-75 rating range. The designed model has been fit through GOF and GOFI values. TPK, CK and PK had a direct effect on STEM skills significantly for student's abilities in preparing lesson plans. Indirect effect to show that the ability of STEM-integrated TPK, PCK, CK, TK, TPACK, PK has an indirect impact on students' ability to plan science lessons.

Keywords: lesson plan, TPACK, STEM, prospective science teacher.

Abstrak: *Penelitian ini bertujuan untuk mengetahui pengaruh TPACK terintegrasi STEM terhadap kemampuan perencanaan pembelajaran IPA dan mengeksplorasi kemampuan perencanaan pembelajaran oleh mahasiswa dalam mengembangkan kompetensi diri untuk menjadi adaptif, profesional, kreatif dan inovatif untuk dibekali keterampilan khusus. Metode penelitian adalah survey dengan pendekatan kuantitatif dan jumlah subjek sebanyak 34 mahasiswa PGSD semester genap tahun akademik 2021/2022. Pengumpulan data menggunakan kuesioner dengan skala likert dan dokumentasi.. Teknik analisis data menggunakan SEM melalui AMOS dan analisis deskriptif. Hasil analisis menunjukkan mahasiswa mampu mengimplemetasikan TPACK terintegrasi STEM dalam rentang penilaian 51-75. Model yang didesain telah fit melalui perbandingan GOF dengan. Hasil analisis direct effect ditemukan TPK, CK dan PK berdampak langsung terhadap kemampuan STEM secara signifikan sedangkan kemampuan TK berdampak langsung terhadap kemampuan mahasiswa dalam menyusun perencanaan pembelajaran. Hasil indirect effect menunjukkan bahwa kemampuan TPK, PCK, CK, TK, TPACK, PK terintegrasi STEM berdampak secara tidak langsung bagi kemampuan mahasiswa menyusun perencanaan pembelajaran IPA.*

Kata kunci: *rencana pelaksanaan pembelajaran, TPACK, STEM, calon guru IPA.*

▪ INTRODUCTION

The skills of 21st century prospective science teacher emphasize collaboration skills, creative thinking skills, critical thinking skills, problem solving skills and ICT skills. Prospective teachers can integrate various pedagogical and ICT skills to support the science learning process (Valtonen, Sointu, Mäkitalo-Siegl, & Kukkonen, 2015). The rapid development of technology to support the learning process is proof that the education and learning sector must be adaptive in facing the Industrial Revolution 5.0. The entry of the 5.0 industrial revolution is synonymous with a synergistic relationship between digital technology without eliminating real human identity (Rukmana &

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Handayani, 2020). Acceleration of educators' pedagogical competence in utilizing technology is directly or indirectly stimulated during the Covid-19 learning period (Winda Purnama Sari & Aprilliandari, 2021).

Graduate Competency Standards for Higher Education Level Education Units that have been established based on Government Regulation Number 4 of 2022 Article 6 Paragraph (4) are graduates who have the knowledge, skills, independence and attitude to discover, develop and apply science and technology that are beneficial to humanity (Peraturan Pemerintah Republik Indonesia Nomor 4 Tahun 2022, 2022). The ability of prospective educators to optimize the use of ICT through integration with TPACK (Technological Pedagogical Content Knowledge) capabilities with a dynamic framework that describes the knowledge and skills of prospective science teachers in designing learning (Rahayu, 2020). TPACK integrates Content Knowledge (CK), Pedagogy Knowledge (PK), Pedagogy Content Knowledge (PCK), Technology Pedagogy Knowledge (TPK) and Technology Content Knowledge (TCK). The effectiveness of teachers to apply the TPACK framework in learning is closely related to the qualifications of educators and teaching experience (Akhwani, 2020; Kaplon-Schilis & Lyublinskaya, 2020). The TPACK framework is used to determine prospective teacher understanding of technology in education to produce effective teaching with technology and the interaction between the technology domain and pedagogical competence and knowledge of the content of learning materials (Cahyani, Azizah, & Evans, 2021). The TPACK framework can be seen in Figure 1 below (Kaplon-Schilis & Lyublinskaya, 2020):

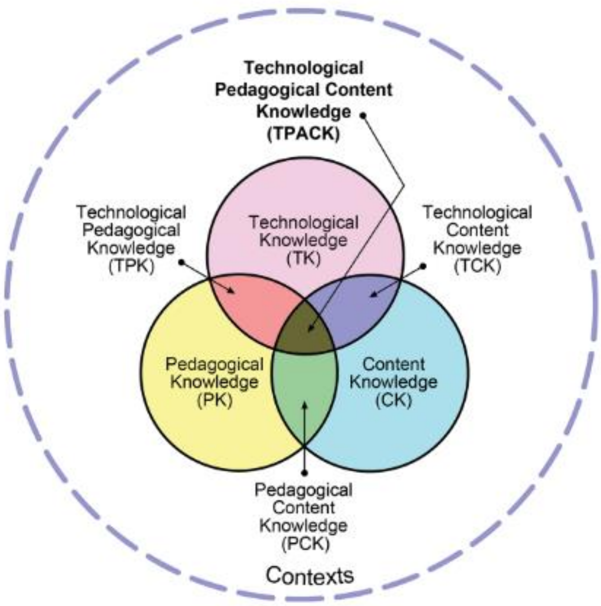

Figure 1. TPACK framework

The TPACK framework is used to prepare prospective science teachers to produce effective teaching with technology and interactions between the technology domain and pedagogical competencies and knowledge of content from science learning materials, so as to be able to support development and implementation capable of supporting 21st century learning and global challenges (Cahyani et al., 2021; Pusparini, Riandi, & Sriyati, 2017; Putri, Hidayat, & Purianingsih, 2020; Tokmak, Incikabi, & Sinan Ozgelen, 2012). The importance of the ability of TPACK possessed by prospective teachers to be used as an effort to improve the quality of education in an effort to realize education in Indonesia (Kaplon-Schilis & Lyublinskaya, 2020; Suyamto, Masykuri, & Sarwanto, 2020). The integration of TPACK with STEM is used as a learning support in developing basic teacher competencies on an ongoing basis to be able to solve problems found in the environment effectively and innovatively (Abdurrahman, Ariyani, Nurulsari, Maulina, & Sukamto, 2020; O. F. Nugroho, Permanasari, & Firman, 2019; Saeng-Xuto, 2019). Exploration of STEM transforms pedagogical practices as integral materials and transitions to teaching and learning through virtual platforms and the use of other technologies (Dhurumraj, Ramaila, Raban, & Ashruf, 2020).

The purpose of this research was carried out to explore the ability of lesson planning by science teacher candidates in developing their own competencies and skills. Thus, prospective science teachers can become adaptive, professional, creative and innovative educators to be equipped with special skills. Prospective teachers who implement TPACK can be used as a basis for realizing education that is Sustainable Development Goals (SDGs) or what is known as Education for Sustainable Development (ESD) (Novidsa, Puwianingsih, & Riandi, 2021). STEM learning stimulates the emergence of "DIY" or "Do it Yourself" skills, namely a culture to encourage students to build, modify, repair and make objects using their own hands. The importance of this research being carried out because the results can be used as a basis for supporting the profile of graduates as professional educators by developing their own skills to be adaptive in any changes that occur, such as curriculum changes, developments in the PISA 2022 measurement level and ready to become job creators.

▪ METHOD

Research Design and Procedure

This research is a quantitative research using a survey method with the aim of exploring the ability of prospective educators in mastering technology through STEM-integrated TPACK skills in the science field. Survey research focuses more on the population, not on related variables or predictive outcomes (Creswell, 2012). The research was carried out at the Universitas Muhammadiyah Bangka Belitung and was carried out from January to September 2022. In detail, research activities are carried out through the following stages in Table 1:

Table 1. Research activities design and procedure

Activities	**Month**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Collect secondary data	■								
Analyze problems globally, nationally and locally		■							
Evaluation and analysis of the results of previous studies		■							
Preparation of STEM integrated TPACK analysis instruments on science learning planning capabilities			■						
Questionnaire instrument validation by validator				■					

and empirical test with 60 elementary teacher student's. The instrument consist of TK, PK, CK, TPK, TCK, PCK, TPACK and STEM with total statements amounted to 60, but after empirically testing through Pearson correlation and reliability through Cronbach's alpha found 55 valid statements
Data collection through questionnaire, portfolio, lesson plan design, 3d hologram media, and several other research-related documents
Descriptive statistical analysis and inference trough SEM-AMOS
Interpretation of result and conclussion

Population and Sample

The population of this study was 150 prospective elementary school teacher and the research sample was 30 students, while 60 students were used for empirical testing of instruments through instrument validity and reliability tests. The sampling technique used cluster sampling with a total of 34 students. The courses used as measurements in the science field are related to science material and learning.

Data Collection

Data was collected using a portfolio assignment, lesson plan design, 3D hologram media, several other research-related documents, and questionnaire. The questionnaire instrumen consist of TK, PK, CK, TPK, TCK, PCK, TPACK and STEM with total statements amounted to 60, but after empirically testing through pearson correlation and reliability through Cronbach's alpha found 55 valid statements. The instrument to made it modification of Hidayat 2019; Melindawati, Apfani, and Suryani 2021; Schmidt et al. 2014; Wijil Septiandari 2019.

Data Analysis

Data analysis techniques used Structural Equation Modeling (SEM) through AMOS and descriptive analysis. SEM analysis begins with modeling TK, PK, CK, TPK, TCK, PCK, TPACK, STEM, and the ability to plan science lessons. The model is declared fit if the GOF and GOFI values match the cut off values. If it doesn't fit, it is necessary to revise the model to be fit according to the model suggestions that appear on AMOS. The fit criteria can be seen in Table 2:

Table 2. Fit Criteria of GOF with GOFI

Goodness of fit index	Cut-off value	Category
Chi-Square	<12.59	Fit
Sig. probabilitas	≥ 0.05	Fit
df	≥ 0	Fit
CMIN/DF	≤ 2.00	Fit
GFI	≥ 0.90	Fit
AGFI	≥ 0.90	Fit
CFI	≥ 0.90	Fit
TLI/NNFI	≥ 0.90	Fit

NFI	≥0.90	Fit
IFI	≤0.90	Fit
RMSEA	≤0.08	Fit
RMR	≤0.05	Fit

Source: (Waluyo, 2016; Yanuarto, Maat, & Husnin, 2020)

▪ RESULT AND DISSCUSSION

Instrumen Validity and Reliability Test Result

The questionnaire instrument used to collect data has been tested for face validity by reviewing the views of experts in science and evaluation. The validation results were strengthened through empirical analysis by comparing the gain scores of the groups using the Pearson correlation. The empirical validity test involved 56 fourth semester elementary teacher education students with a total of 60 statement items. The results of the validity test show that out of 60 items there are 55 valid items and 5 invalid items. Decision making can be seen from rcount > rtable (0.259) or sig. < 0.05 then the item is valid, so the instrument used for measurement consists of 55 statements. Furthermore, the reliability test was carried out using Cronbach's alpha, it was found that the reliability of the instrument was very reliable (0.928), which meant that it would give the same results for many repetitions of measurements. (Subali, 2016).

Result of SEM Analysis via AMOS

Testing the fit of the model as a whole by comparing the results of the criteria of Goodness of Fit (GOF) with the Goodness of Fit Index (GOFI) through Structural Equation Modeling (SEM) (Waluyo, 2016; Yanuarto et al., 2020). This test is simultaneously to test the model of the relationship between variables (path analysis) and obtain a useful model for prediction (structural model and regression analysis). Based on the results of the analysis test, the model modification has been carried out five times because it has not yet reached the cut-off value. The modification was made because theoretically there is a relationship between variables. Schematic modification of the diagram from the previous model regarding the relationship between the STEM-integrated TK, PK, CK, TPK, TCK and TPACK variables on students' learning planning abilities in the field of Science can be seen in Figure 2. The results of the comparative test between the results of the criteria for Goodness of Fit (GOF) and the Goodness of Fit Index (GOFI) can be seen in Table 2.

Table 2. Comparison of gof and gofi criteria result

Goodness of fit index	Cut-off value	Model result	Remarks
Chi-Square	<12.59	0.43	Fit
Sig. probabilitas	≥0.05	0.741	Fit
df	≥0	7	Fit
CMIN/DF	≤2.00	0.62	Fit
GFI	≥0.90	1.01	Fit
AGFI	≥0.90	1.00	Fit
CFI	≥0.90	1.00	Fit
TLI/NNFI	≥0.90	1.75	Fit
NFI	≥0.90	1.14	Fit

IFI	≤0.90	0.73	Fit
RMSEA	≤0.08	0.00	Fit
RMR	≤0.05	0.03	Fit

Source: (Waluyo, 2016; Yanuarto et al., 2020)

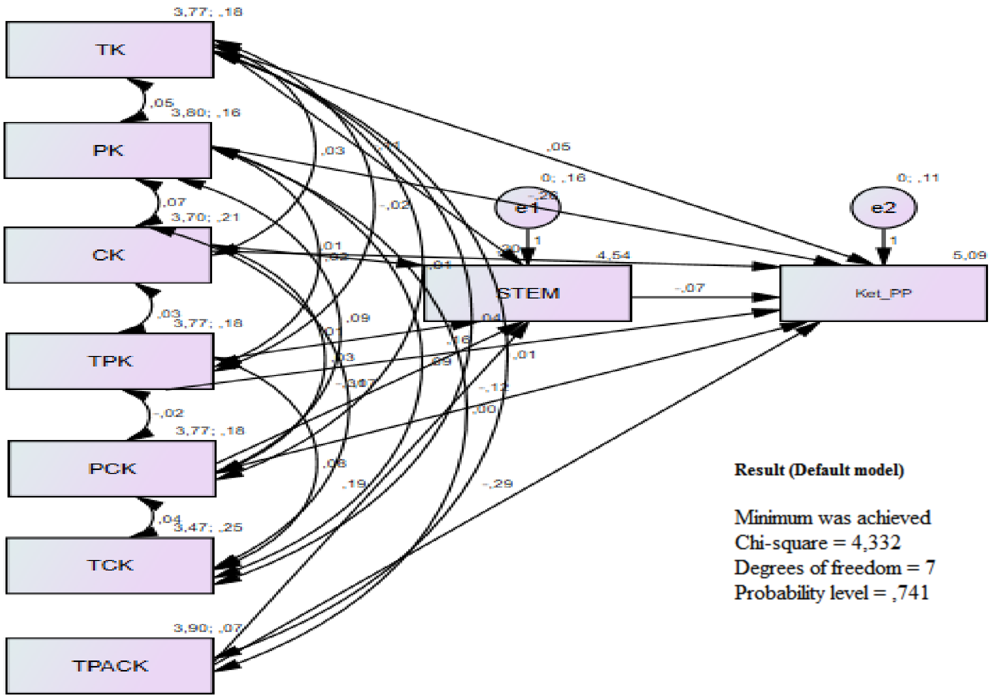

Figure 2. Analysis of the influence of STEM-integrated TPACK on the ability to plan science learning

Based on the results of the analysis in Table 2, it is known that all comparisons of GOF and GOFI criteria are in the fit category that exceeds the cut-off value. The results of this model structure is a modification of the previous model which is known to have five categories that are in the marginal category (close to the minimum cut-off value). This shows that the items tested have fulfilled the prerequisite criteria, so that the stages of searching for structural equation models and testing the hypotheses generated from the regression weight test are continued, which are presented in Table 3 below:

Table 3. Regression weight test result

			C.R.	P
STEM	<---	TPACK	.687	.492
STEM	<---	TK	-.607	.544
STEM	<---	PCK	-1.730	.084
STEM	<---	CK	.059	.953
STEM	<---	TPK	.039	.969
Ket_PP	<---	STEM	-.458	.647
Ket_PP	<---	TK	.284	.776

			C.R.	P
Ket_PP	<---	CK	1.366	.172
Ket_PP	<---	PCK	-.638	.523
Ket_PP	<---	TPACK	-1.228	.219
Ket_PP	<---	TPK	1.040	.298
Ket_PP	<---	PK	-1.220	.223

Judging from the results of the regression test in Table 3, it is known that there is no influence between the STEM-integrated TPACK variable on the ability of prospective teachers to plan integrated learning. In terms of the direct effect results, it was found that the abilities of the TPK, CK and PK aspects had a direct impact on STEM abilities significantly, while Kindergarten abilities had a direct impact on the ability of prospective teachers in preparing lesson plans. The results of the indirect effect show that the ability of STEM-integrated TPK, PCK, CK, TK, TPACK, PK has an indirect impact on the ability of prospective teachers in preparing lesson plans. The results presented in Table 2 are influenced by several factors, namely 1) very few respondents were used as the research sample so that the sample assumptions were not met; 2) the data is not normally distributed because the probability is sig. <0.05 and does not meet the assumption of linearity test; and 3) the results of the comparative evaluation of GOF and GOFI criteria show several aspects whose values are included in the marginal or final cut off value (Waluyo, 2016).

Descriptive Analysis Result

Based on the results of observation and analysis of students' ability to integrate STEM in learning science in various forms of activity, it is known that students optimize Ms. Modified Office Power Point in the form of interactive power point. In addition, students make animated videos using several platforms such as Powtoon, Kinemaster, Canva and other applications that operate resources. Other media such as Quizizz, Flipbooks to Phet Colorado as media for virtual science practicums. The results of the prospective teacher's self-evaluation of his ability to practice and integrate STEM in science learning can be seen in Table 4 below:

Table 4. Result of self-evaluation of prospective science teachers

	≤25	**26-50**	**51-75**	**76-100**
In general, what percentage of you believe that STEM is very effective for learning science?	7	15	8	4
In general, what percentage of you apply STEM (Science, Technology, Engineering, and Mathematics) in your teaching practice?	5	7	20	2
In general, how many percent do you believe that learning should be integrative or combine several studies in fields of science so that students gain comprehensive knowledge	8	8	13	5
In general, how many percent do you	8	10	10	6

believe that learning should be integrative or combine several studies in fields of science so that students gain comprehensive knowledge				
In general, what percentage do you use technology in learning?	7	8	10	9
	7	10	12	5

Judging from the results of student assessments in Table 3, it is known that students justify their ability to implement TPACK integrated with STEM with an assessment of 51-75. In terms of the results of implementing student activities in integrating TPACK with STEM to determine the ability to plan learning, it can be seen in the activity of recycling paper using simple tools and materials. The simple tools and materials in question are using tools that are easy to find and use, such as replacing green screens with photo frames or filter tools or other similar tools. In addition, for STEM activities that are provided through Do It Yourself (DIY) is by innovating STEAM in science learning on the material of light refraction. Students make simple 3D holograms by utilizing inorganic waste such as used bottles. This activity is a support in developing the skills of integrating several scientific studies, so that it can be used as a trigger to achieve integration success of 56% -75%. Examples of products produced can be seen in Figure 3 below:

Figure 3. STEAM practice results through 3D holograms of light refraction material

The results of student activities in making 3D holograms are a form of practical implementation of STEAM in science learning. This activity stimulates students to be able to produce multi-disciplinary products. Students can explain the differences between STEM and STEAM which are implemented in science learning. In addition, can distinguish the roles and functions of each field between science, technology, art and mathematics. The justification for students who reported that they had not been able to apply 76% -100% was because they did not have much experience in integrating several fields so that students tended to lack confidence in implementing it. This is in line with previous research which states that implementation to integrate the dimensions of knowledge and technology greatly influences age and teaching experience (Castéra et al., 2020). The results of the description analysis can be seen in Figure 4 below:

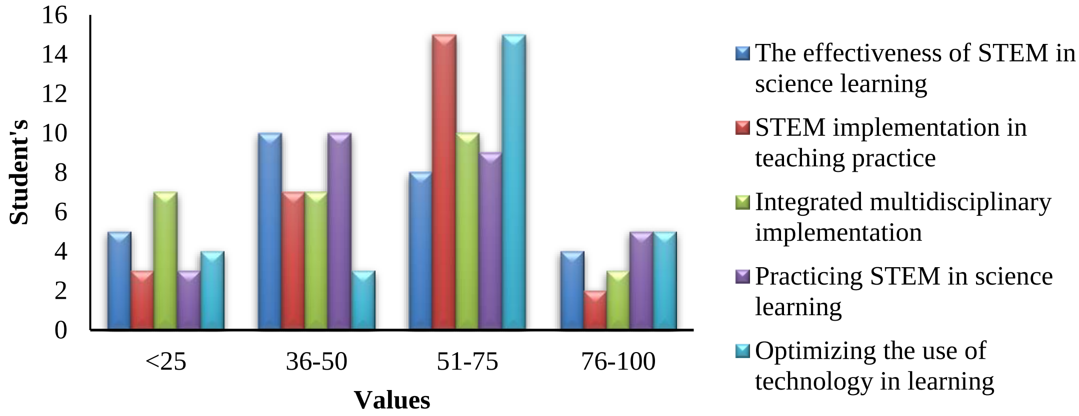

Figure 3. Descriptive analysis result

Based on the results of the descriptive analysis in Figure 4, it is known that there are five students who justify the 76-100 rating because students lack experience in integrating several fields so that students tend to lack confidence in implementing it. Implementation to integrate the dimensions of knowledge and technology greatly influences age and teaching experience (Castéra et al., 2020). Students' ability to plan learning can be seen in the results of an analysis of lesson plans collected by implementing various learning models and the use of technology in learning. Prospective teachers must keep abreast of technological developments that have a great opportunity to support active and efficient learning (Terra, Ridlo, Indrawati, & Hidayah, 2020) as well as being able to facilitate students to improve students' cognitive for example through website-based integrative thematic multimedia (F. Nugroho & Iqbal Arrosyad, 2020). Implementation and integration of learning through STEM-integrated TPACK to determine learning planning abilities from the results of student self-reports and questionnaires can be seen in Figure 5 below:

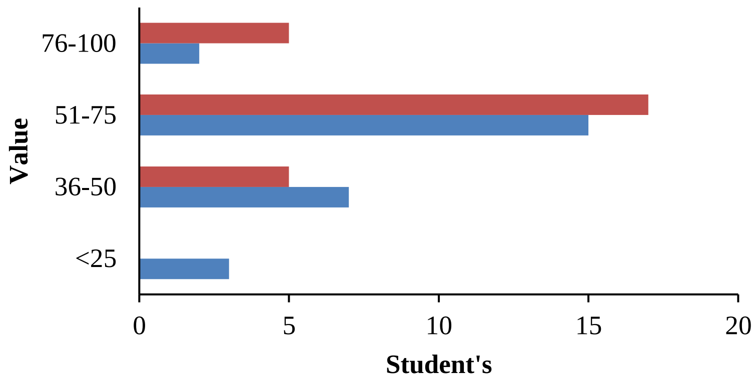

Figure 4. Results of descriptive analysis of the ability to plan lessons. Integrate innovative learning and design learning presented in red and blue color, respectively

Based on the results of the descriptive analysis in Figure 5, it is known that students have realized the importance of designing varied learning by integrating several scientific fields. The majority of students justify their ability to be in the 51-75 range because they have little experience in preparing lesson plans. The results of preparing lesson plans can be seen in Figure 7 below:

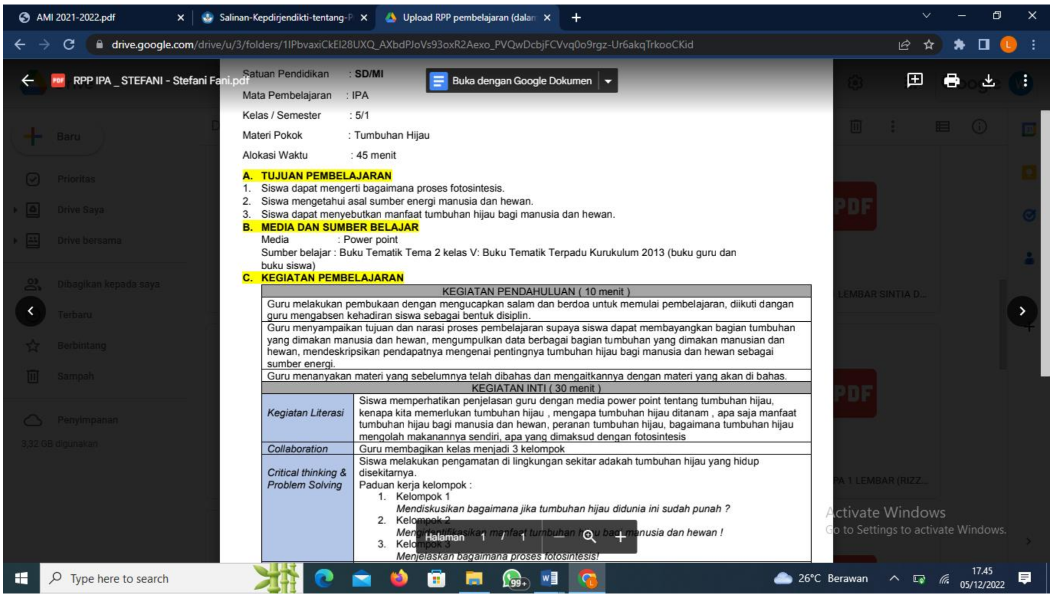

Figure 5. Model-based and integrated lesson plan compilation results

The lesson plans prepared by prospective science teachers attached to Figure 6 above are lesson plans that have implemented TPACK. TPACK is used as a parameter for prospective teachers to determine success in teaching through the use of technology (Schmid, Brianza, & Petko, 2020). TPACK implementation has an effect on scientific literacy, social skills for students (Irmita & Atun, 2018), higher order thinking skills (Zaeni, Rahayu, & Makmuri, 2021), creative products made by students (Septiandari, Riandi, & Muslim, 2020), provide teaching-learning experiences and technology systems to promote collaborative and active learning so as to share information and resources (Cheng, Molina, Lin, Liu, & Chang, 2022). The relevance of TPACK implementation in supporting the performance of prospective teachers through indicators that have been presented at the TPACK level which consists of recognizing, accepting, adapting, exploring and advancing (Lyublinskaya & Kaplon-Schilis, 2022) as well as implemented with relevance to teaching materials, variations in learning approaches/strategies and application of teaching material designs to support the curriculum (Yasa & Handayanto, 2021). Learning by considering the type of media or technology serves to create interaction between learning subjects. An example of selecting and selecting inappropriate media used during the Covid-19 learning period through WAG. The use of WAG too often causes learning to be ineffective because it results in boredom in learning (Rizandi, Puspita, Fatimah, Cantika, & Sari, 2021).

Efforts for future science teacher candidates in facing global challenges in the future by strengthening 21st century skills (I. M. Sari, Yusibani, Irwandi, Sofyan, & Suherman, 2021) is to create learning designs that enhance problem-solving skills (Purwaningsih et al., 2020). The integration of TPACK-STEM abilities can stimulate an increase in the self-skills of prospective teachers as indicated by an increase in self-confidence, in this case it is known that pedagogical knowledge and the lowest in technology knowledge for prospective teachers (Irwanto, Redhana, & Wahono, 2022). TPACK implementation is strongly influenced by the age factor (Restiana & Pujiastuti, 2019) and requires the skills of teachers who can include the content of biology, physics, chemistry, technology, earth sciences and other relevant sciences through learning with a scientific method or approach (IPA) (Akçay & Avcı, 2022). STEM implementation can also be collaborated with project based learning to have a positive influence on students' science process skills in studying physics (Jatmika, Lestari, Rahmatullah, Pujianto, & Dwandaru, 2020). The learning environment that is integrated with technology and implemented through STEM has an impact on increasing the professional competence of teachers in fiber learning increasing the use of digital so that it has a positive impact on the field of teaching and learning (DeCoito & Estaiteyeh, 2022). STEM implementation in learning can be used to develop the potential of both general and blind students (Indriani & Yuli, 2022) through direct or indirect learning or through the development of teaching materials such as STEM-based LKPD to direct learning so that it can provide student learning experiences, stimulate, develop students' science process skills (Febriyanti & Maryani, 2020; Makalunsenge, Yusuf, & Lamangantjo, 2022) and skilled in improving critical thinking skills and scientific literacy through digital literacy which is ultimately able to be skilled in solving problems in real life (F. Handayani, 2020; M. Handayani & Khairuna, 2022; Siti Maisarah, Miriam, Mahtari, & Suyidno, 2022). The integration of PBL with STEM is also considered capable of increasing students' disaster literacy (W. P. Sari, Abdurrahman, & Lengkana, 2022).

▪ CONCLUSION

The integration of TPACK with STEM shows that science teacher candidates can implement STEM-integrated TPACK within the 51-75 rating range. The justification for this assessment was collected by students through self-evaluation of the integration of TPACK with STEM in preparing science learning plans. The results of SEM analysis through AMOS through a comparison of GOF with GOFI in the fit category indicate that a fit model has been achieved. The results of the direct effect analysis found that TPK, CK, and PK had a direct impact on STEM skills significantly, while Kindergarten skills had a direct impact on the ability of prospective science teachers in preparing lesson plans. The results of the indirect effect show that the ability of STEM-integrated TPK, PCK, CK, TK, TPACK, PK has an indirect impact on the ability of prospective teachers in preparing science lesson plans.

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