

Meta-analysis: The effectiveness of the integrated STEM technology pedagogical content knowledge learning model on the 21st century skills of high school students in the science department

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Abstract: This study aims to analyze the effect of the STEM integrated Technology Pedagogical Content Knowledge learning model on the 21st Century skills of high school students majoring in science. This research is a type of meta-analysis research. The sample of this research comes from the analysis of international and national journals indexed by Scopus, SINTA and DOAJ, totaling 12 journals. The sample search was carried out by searching the google scholar database, Sciencedirect, Eric Journal, Taylor and Francis, Wiley Journal, Sage Journal and Emerald. The sampling technique is purposive sampling technique. The data that can be sampled is related to the STEM-integrated TPACK learning model in 21st Century Student skills. The data analysis technique is a quantitative data analysis technique by calculating the Effect Size (ES) and N-Gain values with JSAP software. The results of the study conclude that the application of the integrated STEM Technology Pedagogical Content Knowledge learning model is effective in improving the 21st-century skills of high school students with an effect size value of 1.765 with an N-Gain of 0.56 and an SD value of 0.29. So, the STEM-integrated TPACK learning model is very effectively applied in high school biology learning

Keywords: TPACK Model, STEM, 21st Century Skills

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INTRODUCTION

In the era of the industrial revolution 5.0, the world society experienced a fairly rapid development in all fields (Zorlu & Yusuf, 2021). The field of education is developing very rapidly (Saxen et al., 2019). Education is the basis for becoming a developed country for its human resources (Chun & Abdullah, 2022; Mihadız & Doğan, 2014). The progress of human resources really needs to be encouraged by improving the skills used in the learning process (Mahoney & Zigler, 2006). Skills or competencies have a very large role in achieving the learning objecti-

ves that have been set (Carter et al., 2011). To achieve the appropriate learning objectives, the teacher's contribution is needed in implementing learning effectiveness. The effectiveness of learning will be achieved if teachers and students have high scientific competence (Atabay & Topçu, 2020; Güven, 2010). This is in training students' independence and motivation in learning (Sunaryo et al., 2021).

Competence is a skill possessed by someone to be able to get things done more easily (Karatas & Baki, 2013; Poowanna et al., 2022). In the 21st century, students must be trained to improve critical thinking and problem solving, creative, communication, and collaboration competencies (Chen et al., 2020; Hämäläinen et al., 2017). This is needed by students to make it easier for them to solve various problems that occur in everyday life (Santosa, Razak, Anhar, et al., 2021). So, students who have this ability more easily understand the material being studied. Therefore, teachers as educators must train students to improve 21st century competencies (Sevilla-Pavón, 2019). So, teachers must have the latest learning models that are able to improve students' 21st century competence (Suharyat et al., 2022). Therefore, students' knowledge has a very important role in everyday life (Satria & Sopandi, 2019). So, these competencies are needed by students in practicing creative thinking skills (Noviyani et al., 2022).

The problem that occurs to students in Indonesia at this time is the low competence of the 21st century, especially in critical thinking and problem solving skills (Waluyo & Nuraini, 2020), and low student creativity. In addition, students' communication skills at this time are still low (Maulida et al., 2021), the teacher must have skills in collaborating these four competencies in learning. Based on data from PISA in 2015 Indonesia was ranked 62 of the 70 participating countries that had low critical thinking, creative, collaboration and communication competencies (Sutiyatmini & Maryanto, 2018; Rais et al., 2021). Therefore, the use of technology is the basis for developing 21st century skills in students (Iskandar et al., 2021; Manullang & Satria, 2020). Furthermore, a teacher must make changes in the learning model (Razak & Santosa, 2022).

The Technology Pedagogical Content Knowledge (TPACK) learning model is one of the learning models to support students' 21st century skills. Technology Pedagogical Content Knowledge (TPACK) is a new learning model for teachers that combines aspects of pedagogical technology and content knowledge (Drajati et al., 2018). The learning model is very effective in 21st century learning. This is because all 21st century learning has been based on the use of technology in the learning process. So, the TPACK Learning model integrated with the STEM approach is the teacher's solution in improving the quality of learning. This TPACK learning model is able to improve students' critical thinking skills (Sheffield et al., 2015). Not only that, the TPACK model is able to combine Science, Technology, Engineering and Mathematics (STEM).

STEM is a learning approach that combines knowledge, technology, engineering and mathematics in solving a problem (Hacıoğlu & Gülhan, 2021). Research by Lestari et al. (2018), The STEM approach is able to improve students' critical thinking skills. In addition, the STEM approach is also able to improve student learning outcomes (Wijayanto et al., 2020), So with this technology-based learning, it trains students to improve their critical thinking, creative, collaboration and communication skills (Pahrudin et al., 2021). So, the application of learning models that are integrated with STEM is one solution in improving 21st century skills in students (Santosa, Sepriyani, et al., 2021).

Research by Thohir et al. (2022) The TPACK learning model is very effective in teaching science in high school. Research by Clausen et al. (2019) learning models become more effective teachers in delivering learning materials to students. According to Koh et al. (2017),

TPACK learning model provides effectiveness for teachers and students in conducting learning in high school. Furthermore, research by Benton-Borghi (2013) mentions that the Technology Pedagogical Content Knowledge (TPACK) learning model has an influence on students' 21st century skills. Therefore, this STEM-integrated TPACK learning model will help students grow 21st century skills. According to Chai et al. (2019), the use of the TPACK learning model will help in improving 21st century learning for students. Based on these problems, this study aims to analyze the effect of the integrated STEM Technology Pedagogical Content Knowledge learning model on the 21st Century skills of high school students majoring in science.

METHODS

This research is a type of meta-analysis research. The sample of this research comes from the analysis of international and national journals indexed by Scopus, SINTA and DOAJ, totaling 12 journals. The sample search was carried out by searching the Google Scholar database, Sciedirect, Eric Journal, Taylor and Francis, Wiley Journal, Sage Journal and Emerald. The sampling technique is purposive sampling technique. The data that can be sampled is related to the STEM integrated TPACK learning model in 21st Century student skills in biology, physics and chemistry learning. The data analysis technique is a quantitative data analysis technique by calculating the Effect Size (ES) and N-Gain values with JSAP software. How to calculate Effect size (ES) and Effect Size (ES) criteria can be seen in Table 1 and Table 2.

Table 1. How to Calculate Effect Size (ES) Value

No.	Statistic Data Given	Formulas
1.	Mean and standard deviation in one group	$ES = \frac{X_{posttest} - X_{pretest}}{SD_{pretest}}$
2.	Mean and standar deviation in each group (two group were only done by pottest)	$ES = \frac{X_{Experiment} - X_{Control}}{SD_{Control}}$
3.	Mean and standard deviation in each group (two group performed pre-postest)	$ES = \frac{(X_{post} - X_{pre})_{expe} - ((X_{post} - X_{pre})_{cont})}{\left(\frac{SD_{pre\ cont} + SD_{pre\ expe} + SD_{Post\ cont}}{3}\right)}$
4.	Chi-Square	$ES = \frac{2r}{\sqrt{1 - r^2}}; r = \sqrt{\frac{x^2}{n}}$
5.	t-Count	$ES = t \sqrt{\frac{1}{n_{experiment}} + \frac{1}{n_{control}}}$

Table 2. Criteria for Effect Size (ES) Value

Effect Size	Criteria
$0 \leq ES \leq 0.2$	Low
$0.2 \leq ES \leq 0.8$	Medium
$ES \geq 0.8$	Hight

(Source: Oktarina et al., 2021 Santosa et al., 2021)

RESULTS AND DISCUSSION

Result

From a search of national and international journals indexed by Scopu, SINTA and DOAJ (n= 12 journals) that have links to the research sample, namely the Technology Pedagogical Content Knowledge (TPACK) learning model integrated with STEM related to 21st century skills

in science majors consisting of from biology, physics and chemistry. The search results can be seen in Figure 1.

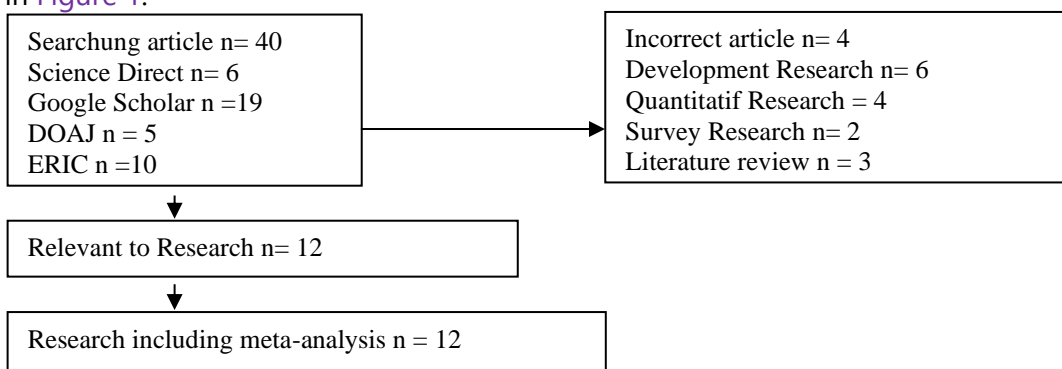


Figure 1. Article Selection Flow Chart for Research Sample

To see in more detail the calculation of effect size (ES) related to the research sample on the STEM-integrated TPACK learning model on the 21st century skills of high school science majors can be seen in Table 3.

Table 3. Category Effect Size (ES) STEM integrated TPACK learning model > 21st Century Skills of students

No.	Author	Variabel Dependent	Design Research	ES	Kategori
1.	Dare et al. (2021)	21st Century Skills	Pretest Postest Control Group	1.43	High
2.	Çeliker (2020)	21st Century Skills	Pretest Postest Control Group	2.51	High
3.	Baran et al. (2021)	21st Century Skills	Pretest Postest Control Group	0.76	Medium
4.	Chaipidech et al. (2021)	21st Century Skills	Pretest Postest Control Group	0.75	Medium
5.	Purwaningsih et al. (2020)	21st Century Skills	Pretest Postest Control Group	2.5	High
6.	Irwanto et al. (2022)	21st Century Skills	Pretest Postest Control Group	2.11	High
7.	Peters-burton & Stehle (2019)	21st Century Skills	Pretest Postest Control Group	3.2	High
8.	Şahin (2021)	21st Century Skills	Pretest Postest Control Group	2.10	High
9.	Başaran (2020)	21st Century Skills	Pretest Postest Control Group	1.7	High
10.	Benek & Akcay (2022)	21st Century Skills	Pretest Postest Control Group	1.56	High
11.	Rizaldi et al. (2020)	21st Century Skills	Pretest Postest Control Group	2.12	Low
12.	Siew (2021)	21st Century Skills	Pretest Postest Control Group	0.44	Low
Mean				1.765	High

Based on Table 3 explaining the effect size (ES) category of the STEM-integrated Technology Pedagogical Content Knowledge (TPACK) learning model on 21st century students' skills, the average effect size (ES) value is 1.765 with a high category. Furthermore, to show the effectiveness of the STEM-integrated TPACK model on the 21st century skills of science majors, the effect size (ES) and N-Gain values were calculated which can be seen in Table 4.

Table 4. Effectiveness of the TPACK + STEM Model > 21st Century Student Skills

No.	21st Century Skills	Class		Effect Size	SD	N-Gain
		Pretest	Posttest			
1.	Critical thinking	60	80	1.765	0.321	0.56
2.	Creative	55	75		0.210	
3.	Communication	65	80		0.345	
4.	Collaboration	60	75		0.321	
	Mean	60	77.5		0.29	

Based on Table 4, it is explained that the STEM integrated Technology Pedagogical Content Knowledge (TPACK) learning model is very effective in improving students' 21st century skills. This can be seen from the Effect size value of 1.79 and the N-Gain value of 0.56 and the Standard deviation (SD) value of 0.29. Thus, the STEM-integrated TPACK learning model is very appropriate to be implemented in the high school science department. This can be seen from the average value of the posttest class > pretest class which is 60 > 77.5. meaning that it is able to improve student learning outcomes of high school science majors. Furthermore, to see the value of STEM-integrated Technology Pedagogical Content (TPACK) for students majoring in science, see Table 5.

Table 5. The average value of TPACK + STEM for students of science majors

No.	Domain	Score	SD
1.	Technology Knowledge (TK)	73.21	0.421
2.	Content Knowledge (CK)	74	0.321
3.	Pedagogical Knowledge (PK)	78.02	0.562
4.	Pedagogical Content Knowledge (PCK)	80	0.241
5.	Technology Pedagogical Knowledge (TPK)	75.62	0.541
6.	Technology Pedagogical Content Knowledge (TPCK)	72	0.371
	Mean	75.475	

Discussion

The results of the study show that the STEM-integrated Technology Pedagogical Content Knowledge (TPACK) learning model is effective in encouraging students' 21st century skills. It can be seen that the effect size (ES) value of students using the STEM-integrated TPACK learning model is 1.79 with high criteria. In addition, the TPACK learning model is very effectively applied in high school science learning, especially in biology, physics and chemistry. This can be seen from the N-Gain value of 0.56. This research is in line with (Çeliker, 2020; Rahman et al., 2021) suggested that the STEM-integrated TPACK learning model is effective in encouraging 21st century skills in students. In addition, research by Dewanti et al. (2020) 21st century skills of students and teachers really need to be improved through the learning process. According to Novitra et al., (2021), technology-based learning is currently more effective in improving students' 21st century skills in critical thinking, problem solving, collaboration, and communication.

The TPACK learning model is one of the learning models that supports 21st century learning (Iskandar et al., 2021; Şahin, 2021). The application of technology-based learning models fosters students' 21st century skills (Tondeur et al., 2017; Tunjera & Chigona, 2020). In addition, teachers who use the TPACK model are more helpful in explaining the subject matter to students. According to Wang and Knobloch (2022). learning model that is integrated with Science Technology Engineering Mathamatic (STEM) makes it easier for teachers and students

to master technology in learning. Therefore, the STEM-integrated TPACK learning model is the main solution in encouraging the improvement of the 21st century skills of science majors.

In 21st century skills, both students and teachers need skills in understanding each subject. According to Izgi-Onbasili et al. (2022) This TPACK learning model helps to grow teacher competence in students' skills in understanding lessons. In addition, according to Chine and Larwin (2022) In this era of learning, learning should be combined with STEM. This is due to the skills of the 21st century science students are encouraged to have high-level thinking skills in solving a problem. The TPACK learning model encourages a teacher to master 21st century technology (Casler-Failing, 2021). Not only that, the TPACK learning model is able to improve student learning outcomes in distance learning (Kaleli, 2021). To note, distance learning especially now requires an integrated learning model on technology (Razak et al., 2021). So, to improve 21st century skills in high school science majors students should apply TPACK to carry out the learning process at school. Because the application of technology in learning makes it easier for teachers and students to achieve predetermined learning goals (Hofer & Grandgenett, 2012; Santosa, Razak, Lufri, et al., 2021; Sudarsana et al., 2019).

CONCLUSION

From the research above, it can be concluded that the application of the integrated STEM Technology Pedagogical Content Knowledge (TPACK) learning model effectively improves the 21st century skills of high school students with an effect size value of 1.765 with an N-Gain of 0.56 and an SD value of 0.34. So, the STEM integrated TPACK learning model is very effectively applied in science learning for high school students in Biology, Physics and Chemistry.

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