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Exploration the skills of teachers: Implementation technological pedagogical content knowledge

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Abstract

Technological pedagogical content knowledge (TPACK) is urgently needed by science teachers in schools in the 21st century. This study aims to describe the effectiveness of teachers in applying the TPACK model. Regarding effectiveness, there is a statistically significant increase in alpha 0.05, which is the average score of teacher skills for classes A and B; the average normalised gain (*n*-gain) score for minimum teacher skills is in the medium category; there is no statistically significant difference in the alpha 0.05 average score of *n*-gain skills of teachers of classes A and B; the minimum effect size is in the medium category. The research sample consisted of 70 junior high school natural science teachers, each class with 35 teachers. The collected data were analysed using paired sample *t*-test, *n*-gain calculation and effect size. The results showed that the increase in teacher skill scores was significant; the average *n*-gain score of teachers' skills was in the medium category; the average score of the average *n*-gain of teachers' skills was not different between classes A and B; and the effect size is in the moderate effect category. The conclusion of this study is that teacher professional education programme activities are effective in implementing the TPACK model. The TPACK model can improve the skills of teachers' higher-order thinking skills in teaching science in schools.

Keywords: Science, teacher, technological, pedagogical, content knowledge

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1. Introduction

1.1. Conceptual or theoretical framework

The Teacher Education Programme in Position is a professional education programme, with level 7 in the Indonesian National Qualifications Framework. The programme is held after the undergraduate or applied undergraduate programme, which demands different competency standards for graduates with applied undergraduate or graduate programmes. The competency standards of graduates in this programme which include attitudes, knowledge and skills are stated in the formulation of the learning outcomes of graduates in the programme.

The lack of knowledge in the preparation of teaching plans and the lack of professional development work show that the ability of teachers to change the paradigm from teacher-centred learning to student-centred learning is still low and the results of the written exam show that the participants of teacher professional education (TPE) and training achieved a minimum average pass score for the whole aspects which include general pedagogy, teaching process, field of study, classroom action research and scientific writing (Irfan, 2020).

The government of the Republic of Indonesia, starting in 2019, implementedin-service TPE to select teachers, especially science teachers in Indonesia, to obtain professional degrees. One of the activities in this TPE is that the participants are required to carry out teaching practicum activities in elementary schools, junior high schools and high schools by applying teaching materials, teaching plans, student worksheets and teaching media.

The requirement to use teaching materials in teaching practicum activities in schools has an internal consistency coefficient value above 75%. In the teaching practice process, teachers apply technological pedagogical content knowledge(TPACK) based on the Industrial Revolution 4.0 platform, which is assessed by education experts and natural science experts using an assessment rubric. The results of research by Soenarno (2019) and Dais et al. (2020) found that teachers still had difficulty implementing TPACK in the learning process in the classroom.

TPACK based on the Industrial Revolution 4.0 platform is an approach model in learning that has several phases, namely (1) analysis, (2) design, (3) development, (4) implementation and (5) evaluation (Hidayu et al., 2019; Joseline et al., 2021; Oktasari et al., 2020).

The design of TPACK teaching materials based on the Industrial Revolution 4.0 platform is interpreted as a preparatory activity for the implementation of learning that applies the latest learning elements in the 21st century and is integrated in the components and stages of teaching that will be carried out to achieve the goals that have been set.

TPACK is a basic framework integrating technology in the teaching process, including neuroscience-based teaching, teaching approach (Science, Technology, Engineering, Arts and Mathematics), higher-order thinking skills (HOTs), 21st-century competency demands,communication, collaboration, critical thinking, creativity and literacy skills. Hidayuet al.(2019) stated that TPACK is very much needed by teachers to deal with teaching 21st-century skills.

1.2. Related research

A teacher in the Industrial Era 4.0 of the 21st century is expected to be an agent of reform. The reforms that can be carried out can start from teaching planning activities, implementation and evaluation to follow-up activities. For this reason, it is necessary to understand some of the

characteristics of 21st-century innovative learning designs that will be applied in making teaching plans.

The implementation of the latest elements in the teaching plan component lies inindicators of competency achievement, teaching objectives, preliminary, core and closing activities and teaching assessments. This is in line with the plan to strengthen student characteristics in the 2013 curriculum (Kemendikbud, 2018).

The difference is in the TPACK element.One of the characteristics of teaching natural science is applying the TPACK approach based on the Industrial Revolution 4.0 of the 21st century, namely the collaboration of students and teachers in terms of pedagogical knowledge, technology knowledge, content knowledge, pedagogical content knowledge, technological pedagogical knowledge and technological content knowledge (Hidayu et al., 2019; Koehler, 2014; Miyarso, 2019).

The problem in this research is how is the effectiveness of teachers in applying the TPACK in teaching natural science materials. Regarding effectiveness, (1) there is a statistically significant increase in alpha 0.05 the average score of teacher skills for classes A and B; (2) the average normalised gain (*n*-gain) score for minimum teacher skills is in the medium category; (3) there is no statistically significant difference in the alpha 0.05 average score of *n*-gain skills of teachers of classes A and B; and (4) the minimum effect size is in the medium category.

1.3. Purpose of the study

This study aims to describe the effectiveness of teachers in applying the TPACK model, namely: (1) to describe the improvement of teachers' skills in applying the TPACK model in teaching sciences, (2) to analyze the effect size of applying the TPACK model in classroom learning. Regarding effectiveness, there is a statistically significant increase in alpha 0.05 the average score of teacher skills for classes A and B; the average normalised gain (*n*-gain) score for minimum teacher skills is in the medium category; there is no statistically significant difference in the alpha 0.05 average score of *n*-gain skills of teachers of classes A and B; and the minimum effect size is in the medium category.

2. Methods

2.1. Research model

This research is pre-experimental using a one-shot case study design with a non-randomised control group pre-test and post-test model, as shown in Table 1(Allen, 2017; Ramdani et al., 2021). Based on this design, each class is given a pre-test and post-test and application of the same Industrial Revolution 4.0-based TPACK model.

Table 1

Research Design (Ramdani et al., 2021)

Group	Pre-test	Treatment	Post-test
A	O_1	X	O_2
B	O_3	X	O_4

Remarks: O_1 and O_3 pre-test;O_2 and O_3 post-test; and $X$is the same treatment.

2.2. Participants

The sample consisted of 70 junior high school natural science teachers who took part in TPE activities in 2020–2021, with class A and class B having 35 teachers each.(1) there is a statistically

significant increase in alpha 0.05 the average score of teacher skills for classes A and B; (2) the average normalised gain (*n*-gain) score for minimum teacher skills is in the medium category; (3) there is no statistically significant difference in the alpha 0.05 average score of *n*-gain skills of teachers of classes A and B; and (4) the minimum effect size is in the medium category.

2.3. Data collection tools

The data collection tool in this study used an observation sheet on the ability to apply TPACK with procedures, namely 1) observing the implementation of TPACK when the teacher taught in class; 2) check the list of scores (1,2,3,4 and 5) on the list of observation sheets according to the teacher's ability level; and 3) analyse the teacher's ability to apply TPACK.

2.4. Data collection process

The data collection process included (1) validating learning tools and research instruments, (2) science teachers teaching in class by applying TPACK, (3) observers giving scores on observationsheets according to teacher activities, (4) data tabulation and (5) data analysis using SPSS 21.

2.4.1. Implementation of the TPACK model based on theIndustrial Revolution 4.0 platform

The implementation of the TPACK modelbased on the Industrial Revolution 4.0 platform consists of five steps of activities:

1. Analysis. Natural science teachers analyse core competencies, basic competencies, competency achievement indicators, learning objectives, teaching models, teaching approaches, teaching strategies, teaching methods, natural science materials, TPACK media based on the Industrial Revolution 4.0 platform and evaluation techniques.
2. Design. Natural science teachers design teaching plans, student worksheets and TPACK media based on the Industrial Revolution 4.0 platform and evaluation techniques.
3. Development. Natural science teachers make teaching plans, student worksheets and TPACK media based on the Industrial Revolution 4.0 platform and evaluation questions that are validated by two assessors.
4. Implementation. Natural science teachers apply teaching plans, student worksheets and TPACK media based on the Industrial Revolution 4.0 platform and evaluate teaching practice activities in the classroom.
5. Evaluation. The natural science teacher evaluates after applying the TPACK model based on the Industrial Revolution 4.0 platform.

The natural science teachers' skills in applying the TPACK model the total score obtained by the teacher after carrying out teaching practice in class, witha total of three cycles. The skills of implementing TPACK based on the Industrial Revolution 4.0 platform were assessed by two assessors using the rubric for assessment of teaching practice in the classroom using scores: 1 (very poor), 2 (less), 3 (enough), 4 (skilled) and 5 (very skilled).

2.4.2. Learning tool validation and reliability

The learning tools applied by the teacher in carrying out teaching practices in the classroom consist of two sets. All sets of learning tools were validated by two expert assessors of science education. Validation analysis used the Gregory analysis (Arlini et al., 2017), as shown in Table 2,to

calculate the value of the coefficient of internal consistency (internal validation) using Equation (1) and to determine the category in Table 2.

The results of the average internal validation scoresshow that (1) lesson plan = 87.00, (2) student worksheets = 90.33 and (3) instructional media = 87.33, which is greater than 0.8 including the high category.This is eligible for use in research.

Table 2

Gregory Validation Analysis Tabulation

	Expert assessment	
	Weak relevance (score 1 or 2)	Strongrelevance (score 3 or 4)
Weak relevance expert assessment (item is worth 1 or 2)	A	B
Strongrelevance expert assessment (item is worth 1 or 2)	C	D

$$\text{Internal consistency coefficient (internal validation)}=\frac{D}{A+B+C+D} \quad (1)$$

Remarks:

A = Both experts give weak relevance.

B = The first expert gives strong relevance.
The second expert gives weak relevance.

C = The first expert gives weak relevance.
The second expert gives strong relevance.

D = Both experts give strong relevance.

Table 3

Content Validation Category (Arliniet al., 2017, p. 184)

Interval	Category
>0.8	High
0.4–0.8	Medium
<0.4	Low

Analysis of the reliability of the device to calculate the level of percentages of agreements between the two raters choosing ‘yes’ or ‘no’ used formula (2) (Grinnell, as citied in Sumaryantoand Lestari, 2015).

The results of the analysis of the reliability of teaching devices show that (1) lesson plans = 99.85, (2) student worksheets = 98.85 and (3) instructional media = 96.88, which is greater than the lower limit of the reliability coefficient of 0.75, meaning that all instruments have reliable research.

$$\text{Percentage of agreement } (R) = \frac{\text{Agreement (A)}}{\text{Disagreement (D)}-\text{Agreement (A)}} \times 100\% \quad (2)$$

The scores obtained from three cycles of teaching practice in the classroom are compared by calculating the *n*-gain formula, as in Equation (3), and categories, as shown in Table 3 (Meltzer, as citied in Lestari et al., 2021, p. 2007).

$$n-g=\frac{x_{\mathrm{m}}-x_n}{100-x_{\mathrm{n}}} \quad (3)$$

Remarks:

n-gain = normalised gain.
X_m = Industrial Revolution 4.0 platform TPACK application skill pre-test score.
X_n = Industrial Revolution 4.0 platform TPACK application skill post-test score.

Table 4

The n-gain Categories (Lestari et al., 2021, p. 2007)

Interval	Category
n-gain>0.7	High
0.3 ≤ *n*-gain ≤ 0.7	Medium
n-gain<0.3	Low

The significance between the teacher skill scores of implementing TPACK based on the early Industrial Revolution 4.0 platform and the teacher skill scores of the last Industrial Revolution 4.0 platform was investigated by conducting a paired sample t-test. It is important to know how significant the impact of implementing the TPACK model based on the Industrial Revolution 4.0 platform is.

The data analysis technique of paired sample t-test was carried out using SPSS version 21. The assumption test, namely the normality test, had to be carried out before the paired sample *t*-test and independent *t*-test. After the independent *t*-test was performed, the effect size was calculated. Effect size is a method used to measure the effectiveness of a study (Cohen et al., as cited in Lestari et al., 2021, p. 2008).Equation (4) is used to calculate the effect size and the categories are shown in Table 4.

$$\text{Effect size} = \frac{\text{Mean of posttest score} - \text{Mean of pretest score}}{\text{Standard deviation}} \quad (4)$$

Table 5

The Effect Size Categories (Lestari et al., 2021, p. 2008)

Interval	Category
0–0.20	Weak effect
0.21–0.50	Modest effect
0.51–1.00	Moderate effect
>1.00	Strong effect

2.5. Data analysis

Data analysis was carried out using SPSS 21.For the purpose of paired data testing, a normality test was performed using the Kolmogorov–Smirnov statistics. The normality tests for pre-test, post-test and *n*-gain skills of teaching practicum teachers in classes A and B are shown in Tables 5 and 6, respectively.

Table 6

Normality Test on the Values of Pretest,Posttest and n-Gain

	Kolmogorov–Smirnov			Shapiro–Wilk		
Teacher skills	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.115	35	0.136	0.938	35	0.062
Posttest	0.172	35	0.010	0.929	35	0.060
n-gain	0.131	35	0.137	0.943	35	0.068

As shown in Table 6, the significance values for the pre-test and posttest data are 0.062 and 0.060, respectively. While the significance value of *n*-gain is 0.068. All significance values are above 0.05. These results indicate that the pre-test, posttest and *n*-gain data each come from a normally distributed population. Thus, the next paired *t*-test can be applied.

Table 7

Normality Test on the Values of Pretest, Posttest and n-Gain

	Kolmogorov–Smirnov			Shapiro–Wilk		
Teacher skills	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.115	35	0.136	0.938	35	0.062
Posttest	0.154	35	0.034	0.946	35	0.086
n-gain	0.133	35	0.134	0.945	35	0.062

As shown in Table 7, the significance values for the pre-test and posttest data are 0.051 and 0.086, respectively. While the significance value of *n*-gain is 0.068. All significance values are above 0.05. These results indicate that the pre-test, post-test and *n*-gain data each come from a normally distributed population. Thus, the next paired *t*-test can be applied.

For the purpose of testing the independent data variable the average score of *n*-gain skills of classes A and B teachers, the normality test and homogeneity test were carried out using the Kolmogorov–Smirnov statistics. The *n*-gain normality test of teacher skills in classes A and B, respectively, is shown in Table 8.

Table 8

Normality Test on the Values of n-Gain

	Kolmogorov–Smirnov			Shapiro–Wilk		
Class	Statistic	df	Sig.	Statistic	df	Sig.
A	0.131	35	0.137	0.943	35	0.068
B	0.133	35	0.134	0.945	35	0.062

As shown in Table 8, the significance values for the *n*-gain data for classes A and B are 0.068 and 0.062, respectively. All significance values are above 0.05. These results indicate that the *n*-gain data for class A and class B come from a normally distributed population. Thus, the next independent *t*-test can be applied.

The *n*-gain homogeneity test of teacher skills is shown in Table 9.

Table 9

Test of Homogeneity of Variances of n-Gain

	N	*F*	Sig.
Teachers'skills in applying TPACK based on the Industrial Revolution 4.0 platform	30	0.000	0.990

As shown in Table 9, the significance value for the *n*-gain data is above 0.05. These results indicate that the *n*-gain data comes from a homogeneous population. Thus, the next independent *t*-test can be applied.

3. Results

3.1. TPACK model based on the Industrial Revolution 4.0 platform

The TPACK model based on the Industrial Revolution 4.0 platform is an alternative learning model to improve teacher skills using TPACK. There are five phases of the TPACK model based on the Industrial Revolution 4.0 platform, namely (1) analysis, (2) design, (3) development, (4) implementation and (5) evaluation.

The explanation of the stages of the practicum-based virtual lab model and its relationship to each of the indicators of scientific attitudes and science process skills being trained is presented in Table 10.

Table 10

Phases of the TPACK-basedIndustrial Revolution 4.0Platform Model

Phase	Teaching activities skills	Students activities
Phase 1: analysis	Skills in analysing core competencies, basic competencies, indicators of competency achievement, learning objectives, teaching models, teaching approaches, teaching strategies, teaching methods, natural science materials, TPACK media based on the Industrial Revolution 4.0 platform and evaluation techniques	Observing core competencies, basic competencies, competency achievement indicators, learning objectives, identifying TPACK media based on the Industrial Revolution 4.0 platform. science material
Phase 2: design	Skills in designing teaching plans, student worksheets, and TPACK media based on the Industrial Revolution 4.0 platform and evaluation techniques	Reviewing teaching plans, student worksheets and TPACK media based on the Industrial Revolution 4.0 platform
Phase 3: development	Skills in making teaching plans, student worksheets, and TPACK media based on the Industrial Revolution 4.0 platform and evaluation questions	Validating the readability of the contents of teaching plans, student worksheets and TPACK media based on the Industrial Revolution 4.0 platform
Phase 4: implementation	Skills in applying teaching plans, student worksheets, and TPACK media based on the Industrial Revolution 4.0 platform: (1) content knowledge (CK), (2) pedagogical knowledge (PK), (3) technological knowledge (TK), (4) pedagogical content knowledge (PCK), (5) technological content knowledge (TCK), (6) technological pedagogical knowledge (TPK), (7) technological, pedagogical, content knowledge (TPCK) and evaluation of	Working on projects on student worksheets, using TPACK based on the Industrial Revolution 4.0 platform to understand concepts, principles and laws in the natural sciences, doing practice questions.

	teaching practice activities in the classroom	
Phase 5: evaluation	Skills in evaluating after applying the TPACK model based on the Industrial Revolution 4.0 platform.	Conduct group discussions on project performance reports and work on evaluation questions

3.2. Results of effectiveness analysis of TPACK implementation based on the Industrial Revolution 4.0 platform

The effectiveness of the TPACK model based on the Industrial Revolution 4.0 platform was evaluated using a teacher skill test applying TPACK based on the Industrial Revolution 4.0 platform before and after the application of the TPACK model based on the Industrial Revolution 4.0 platform given pre-test and post-test. The average pre-test, post-test and *n*-gain scores of teachers' skills in applying TPACK based on the Industrial Revolution 4.0 platform in classes A and B can be seen in Table 11.

Table 11

Mean of Pretest, Posttest and n-Gain

Aspects of calculation	Average score	
	Class A	Class B
Pretest	49.14	49.28
Posttest	65.71	64.85
n-gain	0.46	0.48

Table 11 shows that the posttest value of the teacher's skills in applying the TPACK model based on the Industrial Revolution 4.0 platform in classes A and B is greater than the pre-test score. This shows an increase in teachers' skills scores after implementing TPACK based on the Industrial Revolution 4.0 platform, in the medium category. Then a paired *t*-test was performed using SPSS version 21, and the results for classes A and B are shown in Table 12.

Table 12

The Results of the Paired t-Test

Pretest–Posttest	Class	*N*	Mean	*S*	df	*t*	Sig. (*p*)*
	A	35	−16.57	8.38	34	−11.67	0.000
	B	35	−16.38	8.66	35	−11.34	0.000

*p = 0.05.

Table 12 shows the results of the paired *t*-test of teacher skills in applying the TPACK model based on the Industrial Revolution 4.0 platform for classes A and B, with a sig value 0.000, which means that there is a significant difference between the pretest and posttest scores. The *t*-value is negative because the post-test score is greater than the pre-test score. In other words, there was an increase in teacher skill scores applying the TPACK model based on the Industrial Revolution 4.0 platform for classes A and B.

Then an independent sample *t*-test was conducted to test the average-gain score to test the hypothesis that there was no statistically significant difference in the alpha 0.05 average score of *n*-gain skills of teachers in applying the TPACK model based on the Industrial Revolution 4.0 platform for classes A and B with using SPSS version 21, as shown in Table 13.

Table 13

The Results oftheIndependentSamples t-Test

		α	Sig. (2 tailed)
Teachers' skills in applying the TPACK model based on the Industrial Revolution 4.0 platform	Equal variance not assumed	0.05	0.708
	Equal variance not assumed	0.05	0.708

Table 13 shows the results of the independent sample *t*-test of teacher skills in applying the TPACK model based on the Industrial Revolution 4.0 platform for classes A and B, with a sig value (2-tailed) is greater than 0.05, which means that there is no significant difference in the *n*-gain mean score of teachers' skills in applying the TPACK model based on the Industrial Revolution 4.0 platform that is significant between classes A and B.

The results of the effect size test to determine the effectiveness of the TPACK model based on the Industrial Revolution 4.0 platform are shown in Table 14.

Table 14

The Results oftheEffect Size

Class	Effect size of theteachers'skills	Category
A	0.65	Moderate effect
B	0.57	Moderate effect

Table 14 shows the effect size values of teacher skills in applying the TPACK model based on the Industrial Revolution 4.0 platform in classes A and B are 0.65 and 0.57, respectively, including in the moderate effect category, fulfilling the requirements for the effectiveness of the TPACK model based on the Industrial Revolution 4.0 platform.

Based on the analysis of the data and findings, the following is a discussion of the research results. The application of the TPACK model based on the Industrial Revolution4.0 platform, as shown in Table 10, consists of five phases, namely analysis, design, development, implementation and evaluation; the training for natural science teachers resulted in an increase in teacher skills in applying the TPACK model based on the Industrial Revolution 4.0 platform.

Farikah and Malik (2020) stated that the ability of teachers to apply TPACK was at sufficient criteria. Koehler (2014) stated that in the Industrial Revolution 4.0, graduates of junior high school, high school, college and higher education institutions need to master data literacy skills, technological literacy and human literacy in the science learning process. With the presence of the development of science and technology, one way to improve the quality of science learning is the application of TPACK (Ramamuruthy et al., 2021).

Natural science teachers who took part in the TPE activities in 2020–2021, Indonesia, are required to carry out teaching practices in junior high schools. Natural science materials made by the teacher include (1) temperature and heat, (2) energy, (3) structure and function of plant tissue, (4) digestive

system, 5) inheritance, static electricity and (6) dynamic electricity. Based on the material, student worksheets, teaching media and evaluation were made.

These teaching materials were developed into teaching materials adapted to the applicable science curriculum in Indonesia. Teaching materials consist of teaching plans, student worksheets, TPACK media based on the Industrial Revolution 4.0 platform and evaluation. The product development of teaching materials is guided by assessors and the product is validated by education experts and science experts. The requirements for teaching materials applied in teaching practice in junior high schools are to meet the internal consistency coefficient with a high category.

4. Discussion

Based on the results of the analysis of the coefficients of internal consistency and reliability, it was found that the average value of internal validation was (1) lesson plan = 87.00, (2) student worksheets = 90.33 and (3) instructional media = 87.33, which was greater than 0.8 and included in the high category; it qualifies for use in research.

The results of the analysis of the reliability of teaching devices showed that (1) lesson plans = 99.85, (2) student worksheets = 98.85 and (3) instructional media = 96.88, which is greater than the lower limit of the reliability coefficient of 0.75, meaning that all research instruments are reliable.

This means that the assessors in charge of the 2020–2021 Teacher Profession Programme activities at Makassar State University have succeeded in fostering natural science teachers in making quality teaching material products. The product is feasible to be applied in teaching practice activities in junior high schools.

This finding is supported by several research results including that the inquiry-based teaching materials, creative techniques, integrated science and social meet the validity requirements (Abdigapbarova et al.,2022; Cahyati & Yohandri, 2020; Habibi et al, 2018; Hartati et al, 2019; Wahyu, 2016).

The integration of technology into teaching has become increasingly common in the educational environment in the 21st century. Natural science teachers in junior high schools need to be more creative in designing lessons that are integrated with technology and have the ability to choose the type of technology to be used in the classroom.

TPACK can serve as a beneficial framework for science teachers who wish to incorporate technology into their natural science lessons as a process of designing at once and integrating technology into natural science lessons.

Natural science teachers who took part in teaching practice activities in junior high schools in TPE are required to have the skills to apply the TPACK model based on the Industrial Revolution 4.0 platform so that students understand more quickly the concepts of natural science subject matter and can find out the benefits in everyday life, in the fields of technology, social and economics. If students understand and know these benefits, it will increase their interest and motivation in studying natural sciences and will improve their learning outcomes.

Table 10 shows that the post-test scores for the skills of teachers to apply the TPACK model based on the Industrial Revolution 4.0 platform in classes A and B are greater than the pre-test scores. This shows an increase in teacher skill scores after implementing TPACK based on the Industrial Revolution 4.0 platform, in the medium category.

This shows that the TPACK model based on the Industrial Revolution 4.0 platform can train teachers' skills in applying TPACK in teaching natural sciences, such as research by Akhwani and Rahayu (2021) found that the average score of teacher skills in applying TPACK is still in the low category of 3.02.

Paired *t*-test was used to test the statistically significant increase in post-test scores with SPSS version 22. Before the paired *t*-test was carried out, the assumption of normality was first tested to increase the pre-test and post-test scores of teachers' skills in applying the TPACK model based on the Industrial Revolution 4.0 platform with the Kolmogorov–Smirnov test.

Tables 7 and 8 show that the results of the normality test for teachers' skills in applying the TPACK model based on the Industrial Revolution 4.0 platform for the pretest, post-test and *n*-gain scores for class A were 0.051 and0.086 and class B were 0.068 and0.062. This means that the sample data comes from a normally distributed population

Table 12 showed that the value of sig. 0.000 is smaller than the value of .05, which indicates that the post-test score is greater than the pretest score. In addition, in Table 12, *t* is negative, namely −11.67 in class A and −11.34 in class B, which indicates that the post-test score is greater than the pre-test score. In other words, statistically at the 0.05 significance level, there was an increase in the skill scores of classes A and B teachers after applying the TPACK model based on the Industrial Revolution 4.0 platform.

This shows that the stages in implementing the TPACK model based on the Industrial Revolution 4.0 platform can practice TPACK steps based on the Industrial Revolution 4.0 platform. This is in line with Akhwani and Rahayu (2021), who stated that TPACK can be trained to teachers which is one type of knowledge that must be mastered by teachers in the 21st century, although the ability of teachers to integrate all components is not easy (Azhar et al., 2022; Muñoz-Martínez et al., 2022).

The independent sample *t*-test was used to test the statistically significant difference in the *n*-gain score with SPSS version 21. Before the independent variable *t*-test was carried out, first the normality assumption test and homogeneity test were carried out for the *n*-gain score for the teacher's skills in applying platform-based TPACK Industrial Revolution 4.0 with the Kolmogorov–Smirnov test.

Table 8 shows that the results of the normality test for teachers' skills in applying TPACK based on the Industrial Revolution 4.0 platform for the *n*-gain values for classes A and B are 0.068 and0.062, respectively. This means that the sample data comes from a normally distributed population.

Furthermore, Table 8 shows that the results of the homogeneity test of the *n*-gain significance value of teachers' skills in applying TPACK based on the Industrial Revolution 4.0 platform are above 0.05. These results indicate that the *n*-gain data on teacher skills in applying TPACK based on the Industrial Revolution 4.0 platform comes from a homogeneous population. Thus, the independent sample *t*-test can be applied.

The application of the TPACK model based on the Industrial Revolution 4.0 platform in classes A and B resulted in an average score of *n*-gain skills of teachers applying the same TPACK.This is evidenced by the results of Table 12, showing the results of the independent *t*-test of teacher skills in applying platform-based TPACK Industrial Revolution 4.0 classes A and B with a sig. (2-tailed) is greater than 0.05, which means that there is no significant difference in the average *n*-gain score of teachers' skills in applying TPACK based on the Industrial Revolution 4.0 platform that is significant between classes A and B.

In other words, there is no difference in scores. The average-gain skill of teachers in applying TPACK for classes A and B after teachers are trained in TPACK based on the Industrial Revolution 4.0 platform. Sariet al. (2021) stated that TPACK can be trained in teacher reflective practice activities in office, so that teachers become proficient in integrating technology.

Furthermore, to determine the effectiveness of the application of the PACK model based on the Industrial Revolution 4.0 platform on improving teacher skills in applying TPACK classes A and B, an effect size analysis was carried out. The results in Table 13 show that the effect size value of the teacher's skills in applying TPACK in classes A and B are 0.65 and 0.57, respectively, which are included in the moderate effect category, fulfilling the requirements for the effectiveness of the PACK model based on the Industrial Revolution 4.0 platform.

This finding proves that the application of the TPACK model based on the Industrial Revolution 4.0 platform is effective in improving the skills of teachers in implementing TPACK. This is because teachers directly receive guidance from UNM assessors in making learning tools and implementing the steps of the TPACK model based on the Industrial Revolution 4.0 platform as long as teachers participate in the preservice teachers education programme activities.

This is in line with Adipat (2021), who stated that TPACK is an innovative technology that can improve the skills of preservice teachers in teaching subject matter at certain time intervals. Although the application of the PACK model based on the Industrial Revolution 4.0 platform can improve the skills of teachers in applying TPACK, there are still weaknesses. Some teachers are still not ready to implement TPACK because they do not have supporting tools and insufficient internet access.

This research shows that the TPACK model based on the Industrial Revolution 4.0 platform has proven effective to improve the skills of teachers in applying TPACK in science learning. Teacher skills in applying TPACK include seven skill domains that are interrelated with one another, namely CK, mastery skills in the field of study and PK.

The most optimum skills and knowledge of learning processes and strategies so that students' creativity increases and learning objectives can be achieved, TK, skills and knowledge of how to use digital technology, PCK, skills and knowledge of the field of study or learning materials with learning processes and strategies.

TCK, skills and knowledge of digital technology and knowledge of the field of study or learning materials; TPK, skills and knowledge of digital technology and knowledge of learning processes and strategies; and TPCK, skills and knowledge of digital technology, knowledge of learning processes and strategies and knowledge of the field of study or learning materials.

Istiningsih (2020) stated that by training TPACK to teachers, it will have a positive impact on teachers, namely teachers are able to solve problems that arise during online learning activities, provide authentic assessments in learning, improve teacher skills can using technology in the 21st century, where the use of TPACK has nothing to do with gender differences (Cahyani et al., 2021; Istiningsih, 2022; Septiyanti, et al., 2020; Tashbolatovna et al., 2022).

This finding is also supported by several research results, namely science teachers have a skill level in applying TPACK in teaching science, improving the quality of teaching in the classroom, increasing HOTs, increasing scientific literacy students, creating an effective, fun, interesting and creative learning environment (Dais et al., 2020; Dinara et al., 2022; Ella, 2019; Hartati et al., 2019; Joseline et al., 2021; Leni et al., 2021; Sarjoni et al., 2019).

TPACK based on the Industrial Revolution 4.0 platform can affect society and the economy in various ways, communicate on social media, facilitate access to various producers, innovative competitors, increase the use of digital marketing, creative industries, improve the quality of public services, improving the quality of the business environment, collaborative innovation and innovation in various forms of organisation (Amran et al., 2020; Arifin et al., 2022; Mohamad et al., 2019; Prisecaru, 2016; Saria et al., 2021; Seraliyev et al., 2022).

5. Conclusion

In this study, TPACK was based on the Industrial Revolution 4.0 platform in science class. TPACK based on the Industrial Revolution 4.0 platform which was implemented effectively in improving teacher skills in applying TPACK compared to the application of other science learning media.

TPACK based on the Industrial Revolution 4.0 platform is effective as indicated by an increase in the skills of teachers in applying TPACK, which is statistically significant (at = 0.05), and the average *n*-gain of teacher skills in applying TPACK for classes A and B is 0.46 and 0.48, respectively, in the medium category.

The effect size of the teachers' skills in applying TPACK for classes A and B is 0.65 and 0.57, respectively, with a moderate effect category. It is shown that the effectiveness of the TPACK model based on the Industrial Revolution 4.0 platform is strong, and so the TPACK model based on the Industrial Revolution 4.0 platform can be used as an alternative a virtual science teaching model in training teacher skills in applying TPACK based on the Industrial Revolution 4.0 platform in schools.

6. Recommendations

Based on the research results, we propose a TPACK model based on the Industrial Revolution 4.0 platform which can be applied as an alternative natural science teaching model during a pandemic. In addition, the TPACK learning model based on the Industrial Revolution 4.0 platform can also help teachers improve their skills using technology needed in the 21st century.

However, further research is still needed to conduct research by implementing the TPACK model based on the Industrial Revolution 4.0 platform in a larger sample size. It will evaluate the reliability of the TPACK model based on the Industrial Revolution 4.0 platform.

There are some limitations, i.e., the number of participants in this study is relatively small (only 70 natural science teachers), using Google Classroom and Zoom application.The teaching materials included student textbook, student worksheets, lesson plans, syllabus and teacher skill instruments.The application of models only covers the topics of heat and heat transfer. In addition, the number of samples in this study is limited, namely only 75 natural science teachers who were divided evenly between class A and class B.

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Appendix A. TPACK application document

Some examples of the application of the TPACK model based on the industrial revolution 4.0 platform in teaching practice in junior high schools

1. TPACK based on industrial revolution 4.0 platform, Video

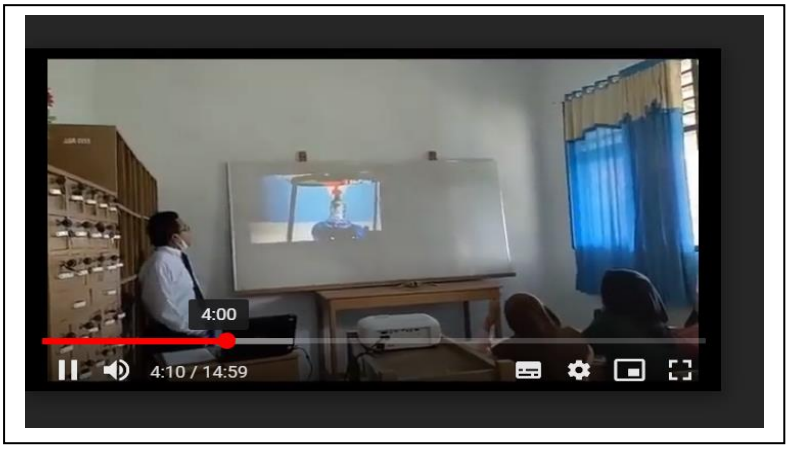

Figure 1. Application of TPACK based on the industrial revolution 4.0 platform with Video link address: https://drive.google.com/file/d/1Sl9t5S7zvglgL2d2yPc9x4goXIixS8MZ/view https://drive.google.com/file/d/1Sl9t5S7zvglgL2d2yPc9x4goXIixS8MZ/view?usp=sharing

2. TPACK berbasis platform revolusiindustri 4.0, Manual

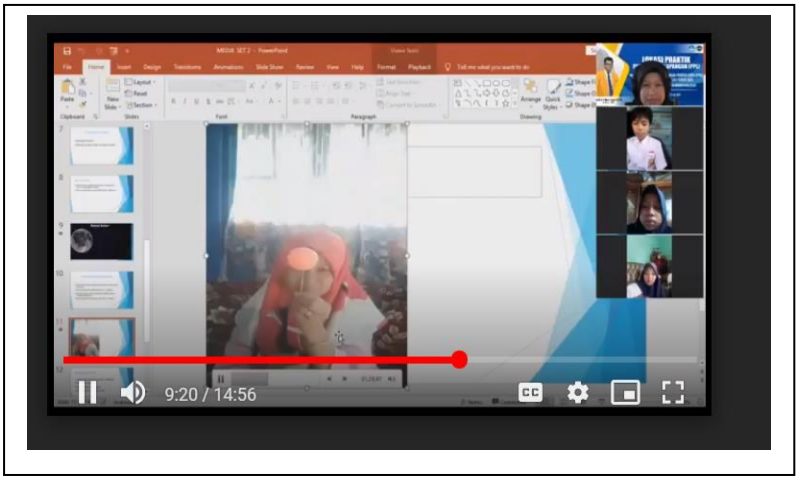

Figure 2. Application of TPACK based on the industrial revolution 4.0 platform with Manual link address: https://drive.google.com/file/d/1ZQ4xaJfvQVy8zvRNAgA24bZ4CLSuBFqV/view https://drive.google.com/file/d/1ZQ4xaJfvQVy8zvRNAgA24bZ4CLSuBFqV/view?usp=sharing

Appendix B. Research instrument

Table B1

Junior High School Teacher Skills Observation Sheet Applying TPACK Indicators Based on the Industrial Revolution 4.0 Platform

No	Observed aspects	Scale					Description / notes
		1	2	3	4	5	
1.	CK, skills and mastery of the field of study or learning material in this case expertise competence, especially on common rail diesel						
2.	PK, skills and knowledge about learning processes and strategies, which are the most optimum so that students' creativity increases and learning objectives can be achieved						
3.	PCK, skills and knowledge about the field of study or learning materials with learning processes and strategies						
4.	PCK, skills and knowledge about the field of study or learning materials with learning processes and strategies						
5.	TCK, skills and knowledge of digital technology and knowledge of the field of study or learning materials						

6.	TPK, skills and knowledge of digital technology and knowledge of learning processes and strategies						
7.	TPCK, skills and knowledge of digital technology, knowledge of learning processes and strategies and knowledge of the field of study or learning materials						
	Total score						

Table B2

Practical Observation Sheet for Teaching Junior High School Teachers By Applying the TPACK Model Based on the 4.0 Industrial Revolution Platform

No	Observed aspects	Scale					Description/ notes
		1	2	3	4	5	
1.	Open teaching skills						
2.	Skills to attract attention and motivate students						
3.	Depth and breadth of material (including no misconceptions)						
4.	Completeness of the material (into the concept)						
5.	The correctness of the concept/procedure						
6.	Skills in using learning methods, models and approaches						
7.	Applying educational learning with a TPACK approach based on the Industrial Revolution 4.0 platform						
8.	Skills to develop a variety of interactions						
9.	Class management skills						
10.	Skills to use time						
11.	Skills in organizing learning resources/or learning materials						
12.	Skills in using information technology in learning						
13.	Skills in using learning media						
14.	Integrating critical thinking skills, creative thinking, reflective thinking and decision making into learning activities through inquiry based activities						
15.	Voice volume and intonation						
16.	Good and correct use of language, spoken and written (according to the subjects being taught)						
17.	Skills to develop HOTs						
18	Skills in using analogies/metaphors						
19.	Non-verbal communication skills (gestures)						
20.	Skills to create a pleasant learning atmosphere						
21.	Modesty of dress/or appearance						
22.	Process assessment skills						
23.	Skills in conducting assessment based on learning outcomes (HOTs)						

24.	Skills to provide reinforcement (reinforcement) and punishment						
25.	Learning closing skills						
	Total score						

Practical Observation Sheet for Teaching Junior High School Teachers By Applying the TPACK Model based on the 4.0 industrial revolution platform

No	Observed aspects	Scale					Description / notes
		1	2	3	4	5	
1.	Open teaching skills						
2.	Skills to attract attention and motivate students						
3.	Depth and breadth of material (including no misconceptions)						
4.	Completeness of the material (into the concept)						
5.	The correctness of the concept/procedure						
6.	Skills in using learning methods, models and approaches						
7.	Applying educational learning with a Technological Pedagogical Content Knowledge (TPACK) approach based on the industrial revolution 4.0 platform						
8.	Skills to develop a variety of interactions						
9.	Class management skills						
10.	Skills to use time						
11.	Skills in organizing learning resources/or learning materials						
12.	Skills in using information technology in learning						
13.	Skills in using learning media						
14.	Integrating critical thinking skills, creative thinking, reflective thinking and decision making into learning activities through inquiry based activities						
15.	Voice volume and intonation						
16.	Good and correct use of language, spoken and written (according to the subjects being taught)						
17.	Skills to develop higher order thinking (HOTs)						
18	Skills in using analogies/metaphors						
19.	Non-verbal communication skills (gestures)						
20.	Skills to create a pleasant learning atmosphere						
21.	Modesty of dress/or appearance						
22.	Process assessment skills						
23.	Skills in conducting assessment based on learning outcomes (HOTs)						
24.	Skills to provide reinforcement (reinforcement) and punishment						
25.	Learning closing skills						
	Total score						