The Effect of TPACK-Based Differentiated Inquiry Learning Model on Motivation and Physics Problem Solving Ability

Derlina[1], Putri Amalia[2], Rajo Hasim Lubis[3], Satria Mihardi[4]

{derlina@unimed.ac.id[1], putriamalia@mhs.unimed.ac.id[2]}

Universitas Negeri Medan, Indonesia[1,2,3,4]

Abstract. This research investigates the motivation and problem-solving abilities of students using a TPACK-based differentiated inquiry learning model in light waves material for class XI at MAN 2 Model Medan. This type of research is a quasi experiment that uses 35 from class XI F1 A as the experimental group and 35 from class XI F1 C as the control group, using cluster random sampling. The results indicate: 1) a significant difference in problem solving abilities between students taught with the TPACK-based differentiated inquiry learning model and conventional learning where $t_{count} > t_{table}$ (2,967 > 1,667). 2) a notable difference in problem solving ability between students who have high motivation and students who have low motivation where $t_{count} > t_{table}$ (6,992 > 1,667). 3) there is an interaction between TPACK-based differentiated inquiry learning model and student motivation with a value of $F_{count(AB)} > F_{table}$ (4,497 > 3,13) and sig < 0,05.

Keywords: TPACK-Based Differentiated Inquiry Model, Motivation, Problem-Solving Ability, Light Waves.

1. Introduction

Education is vital for shaping individuals, communities, and nations. A robust educational foundation allows individuals to realize their potential, acquire knowledge, and contribute to sustainable development. It encourages innovative ideas that can adjust to evolving situations. Curriculum development is essential for enhancing educational quality. One of the government's efforts to improve education in Indonesia involves updating the existing curriculum. This curriculum transition aims to support learning recovery and provide both teachers and students with opportunities for growth. The independent curriculum, inspired by the philosophy of Ki Hadjar Dewantara, serves as a flexible framework that emphasizes essential content and meets learners' educational needs [1]. The independent curriculum is a learning approach that allows students to express their natural talents in a relaxed, enjoyable, and pressure-free environment [2]. To design learning that aligns with the unique characteristics of students—such as their readiness, interests, and learning styles—it is

AISTEEL 2024, September 24, Medan, Indonesia
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DOI 10.4108/eai.24-9-2024.2353275

essential to facilitate understanding of the subject matter, particularly in physics. Physics is closely tied to numeracy skills, as it involves symbols associated with basic mathematics [3]. Numeracy literacy refers to the ability to comprehend and utilize various symbols and numbers associated with basic mathematics to address practical problems in daily life, as well as to analyze information for decision-making [4].

Based on the results of observations of the physics learning process at MAN 2 Model Medan with class XI students totalling 46 people, it was found that 50% of students felt physics was difficult and this was reinforced by interviews with physics teachers found that a small proportion of students were good at problem solving skills in physics and based on research on student motivation as measured in a questionnaire with 20 statements, a value of 58.20% was obtained, which is still quite low. This is of concern to researchers because students must have physics problem solving skills and motivation so that they can understand useful concepts. in terms of improving problem solving skills, teachers can improve problem solving skills in students by meeting the learning needs of each student, such as student learning styles. Taking into account the different learning needs of students in the classroom and assuming that students in the classroom do not have the same learning style.

One effective approach to enhance problem-solving skills is differentiated learning. This method involves creating a diverse classroom environment and offering students various opportunities to engage with content, process ideas, and improve their individual outcomes, thereby enabling more efficient learning [5]. Differentiated learning must be shaped by a teacher's mindset that assumes that every child can grow and develop optimally according to his or her abilities [6]. Teachers require a structured and logical learning model to effectively achieve educational objectives, particularly in differentiated learning. One effective model is the inquiry-based learning approach, which centers on student involvement and is particularly suitable for teaching physics. The integration of differentiation and inquiry has been shown to be both effective and efficient in designing a teaching process that lays a strong foundation for students. This approach enhances students' cognitive skills by encouraging them to think systematically, critically, logically, and analytically through investigative activities, ultimately improving their problem-solving abilities. However, there are still other things that cause students to be difficult in solving problems in physics, namely the lack of development and mastery of technology in learning, especially in physics learning. The problem faced by students in learning physics at school is students' problem-solving ability in understanding and imagining physics concepts that are often too abstract and mathematical so that they require sophisticated analytical structures.

Ertmer & Ottenbreit-Leftwich [7] In line with that, it says that good learning is when students can use relevant information and communication technologies as useful pedagogical tools. This is so that educators can prepare students with 21st century skills so that they can adapt to the times. Therefore, TPACK can be used as a solution in overcoming this problem. TPACK is a structure that combines three main components: technology, instruction, and content or knowledge materials [8]. The integration of technology, pedagogy and content certainly provides new challenges for teachers in improving the process and learning outcomes of students in the 21st century. Physics is a difficult subject because to understand its concepts a student must do practical activities or illustrations that help students understand more deeply.

Therefore, this research aims to find out The Effect of TPACK-Based Differentiated Inquiry Learning Model to Increase Motivation and Physics Problem Solving Ability.

2. Methods

This study employs a quasi-experimental design aimed at examining students' motivation and problem-solving skills when using the TPACK-based differentiated inquiry learning model in the context of light waves. This research was conducted at MAN 2 Model Medan with a population of XI F1, F2 and F5 students totalling 481 students. the sample in this case is part of the population taken using *cluster random sampling* technique from random classes, namely class XI F1 A with 35 people as the experimental class and XI F1 C with 35 people as the control class. Data collection involves a problem-solving skills test and a learning motivation questionnaire. The questions for the problem-solving ability test are designed based on Polya's indicators and are presented in the form of descriptive questions, while the questionnaire given is a questionnaire containing 20 questions. Respondents are restricted to selecting from the answer choices provided by the researcher and cannot offer any other responses beyond those available as options. Each item in the questionnaire is assigned a weighted score.:

Table 1. Questionnaire Score

Statement	Score
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

Before conducting the experiment, the researcher identified the problem and research objectives, followed by compiling the instrument set and then validated by 3 experts. The validated instruments were then tested first in small and large classes, then empirical tests were carried out on the problem solving ability test items. Empirical tests are carried out to measure the validity, reliability, difficulty level test and item differentiation test. So that the instrument is declared suitable for use, before carrying out the research, The researcher administered a learning motivation questionnaire to identify students with low and high motivation levels, followed by a pretest of problem-solving ability in both the experimental and control classes. This pretest aimed to assess the students' initial abilities. Subsequently, the experimental class received treatment through the TPACK-based differentiated inquiry learning model. Learning was carried out for 5 meetings with light waves material. At the final meeting, researchers conducted a post-test to measure students' final abilities, the post-test was carried out in both experimental and control classes. Post-experiment researchers describe the data, performing normality test, homogeneity test, N-gain test and Hypothesis Test. This research hypothesis test uses the t test and Anova test (Analysis of Variance) using SPSS version 25 to get a conclusion in answering the problem formulation.

3. Results and Discussion

The research yielded the following data :

3.1 Pretest Data of Students' Problem Solving Ability

The pretest results for the problem-solving abilities of both the experimental and control classes are shown in the table below :

Table 2. Description of Pretest Data of Problem Solving Ability of Students

Experiment Class				Control Class			
Value	F	Average	Standard deviation	Value	F	Average	Standard deviation
19.64 – 26.14	11	30,77	7,17	17,86 - 23,85	6	28,78	5,74
26.15 – 32.65	12			23,86 - 29,85	13		
32.66 – 39.16	6			29.86 – 35.85	12		
39.17 – 45.67	6			35.86 – 41.85	4		

3.2 Posttest Data of Students' Problem Solving Ability

The posttest results for the problem-solving skills of both classes are recorded in the table below :

Table 3. Description of Posttest Data of Students' Problem Solving Ability

Experiment Class				Control Class			
Value	F	Average	Standard deviation	Value	F	Average	Standard deviation
67.86 – 74.85	2	85,31	6,22	66-72	3	80,76	6,60
74.86 – 81.85	6			73-79	14		
81.86 – 88.85	13			80-86	12		
88.86 – 95.85	14			87-93	6		

3.3 Normality Test

A normality test is a prerequisite before conducting hypothesis testing. The Shapiro-Wilk test is used to evaluate the normality of the pretest data with a significance level of $\alpha = 0.05$. The aim of this normality test is to determine whether the two samples originate from populations with a normal distribution. After processing the data, the results of the pretest normality test are summarized in the following table :

Table 4. Normality Test of Experimental and Control Class Pretest

Class Data	Shapiro-wilk Table	Sig.	Conclusion
Experiment Class	0,952	0,126	Normal
Control Class	0,979	0.742	Normal

Normality testing for the student problem-solving ability data was also conducted on the posttest. The results of this normality test can be found in the following table :

Table 5. Normality Test of Experimental and Control Class Posttest

Class Data	Shapiro-wilk Table	Sig.	Conclusion
Experiment Class	0,960	0,222	Normal
Control Class	0,926	0,168	Normal

Based on the table above, the results of the normality test analysis at a significant level of 5% for each sample obtained a p (sign) value > 0,05, then H_0 is accepted, so it can be concluded that the data is taken from a normally distributed population.

3.4 Homogeneity Test

The homogeneity test for the variance of the sample classes aims to determine if the two samples come from a homogeneous population. This assessment is crucial for confirming whether the samples used in the study accurately represent the overall population. The homogeneity test for the two classes was conducted using the Levene Test, with a significance level of $\alpha = 0.05$. The findings of this homogeneity test are detailed in the table below:

Table 6. Homogeneity Test

		Levene Statistic	df1	df2	Sig.
PSA Results	Based on Mean	2,428	1	68	,124
	Based on Median	2,296	1	68	,134
	Based on Median and with adjusted df	2,296	1	66,359	,134
	Based on trimmed mean	2,372	1	68	,128

Homogeneous if the value of sig > 0,05. So based on the data in the table, it is known that the value *sig based on mean* (Sig > 0,05), then the class is homogeneous

3.5 N-Gain Test

The N-gain test is designed to assess the extent of improvement in students' problem-solving skills. According to Polya, the indicators for problem-solving ability are categorized into four components. The data reflecting the enhancement of problem-solving skills at each stage is displayed in the following table :

Table 7. Data on the Results of Students' Ability Improvement

Stages of Problem Solving	pretest	posttest	N-gain	Interpretation
Understanding the problem	37,76	95,92	0,934	High
Developing a solution strategy	29,59	87,76	0,826	High
Solving the problem	18,37	77,14	0,720	High
Rechecking the answer	32,65	82,49	0,770	High
Average	29,59	86,33	0,81	

The table above indicates that the experimental class shows a significant improvement in their ability to select problem-solving strategies.

3.6 Hypothesis testing

In this study, hypothesis testing used the t test and *Anova* test.. The following describes the results of hypothesis testing using the t test and *Analysis of Variance* (Anova):

3.6.1 Hypothesis Test I

The hypothesis testing for the pretest data was conducted using a two-tailed t-test. This test was performed to assess whether the initial abilities of students taught with the TPACK-based differentiated inquiry model were equivalent to those of students taught through conventional methods. The details of the calculations for the pretest hypothesis test are provided in the table below :

Table 8. Summary of Hypothesis Test Calculations for Pretest Data

Data	Average	t_{count}	t_{table}	Conclusion
Experiment Class	30,77	1,28	1,997	Accept H_0
Control Class	28,78			

Based on the table obtained $t_{count} < t_{table}$ means H_0 is accepted so it can be concluded that experimental and control students have the same initial solving ability before being given treatment. After conducting a two-party t test, Next, we used one-sided t test to see the difference of TPACK-based differentiated inquiry learning model on students' problem solving ability. The results of the one-party t test calculation using posttest data are shown in the following table:

Table 9. Summary of Posttest Data Hypothesis Test Calculations

Data	Average	t_{count}	t_{table}	Conclusion
Experiment Class	85,30	2,967	1,667	The problem solving ability of experimental class students is higher than the control class
Control Class	80,76			

The results indicate that $t_{count} > t_{table}$ leading to the rejection of H_0 and the acceptance of H_a. Therefore, it can be concluded that there is a difference in problem-solving abilities among students taught using the TPACK-based differentiated inquiry learning model on the topic of light waves in class XI MAN 2 Model Medan.

3.6.2 Hypothesis Test II

The t-test for the pretest data is performed to assess whether the initial abilities of students with high motivation are comparable to those of students with low motivation. The calculations for the hypothesis test on students' problem-solving abilities are detailed as follows:

Table 10. Pretest Hypothesis Between students with high motivation and low Motivation

Data	Average	t_{count}	t_{table}	Conclusion
High Motivation Students	30,44	1,167	1,997	Accept H_0
Low Motivation Class	28,70			

Based on the table, it can be seen that $t_{count} < t_{table}$ means H_0 is accepted so It can be concluded that students with high motivation and those with low motivation possess similar initial problem-solving abilities. After performing a pretest hypothesis for both groups, a posttest hypothesis test is conducted to differentiate the problem-solving skills between high-motivation and low-motivation students. The results of these calculations are presented in the following table :

Table 11. Posttest Hypothesis between students with high motivation and low motivation

Data	Average	t_{count}	t_{table}	Conclusion
High Motivation Students	86,46	6,992	1,667	The problem-solving ability of highly motivation students is higher than that of low-motivated students
Low Motivation Class	77,58			

The results indicated that $t_{count} > t_{table}$ means leading to the rejection of H_0 and acceptance of H_a. so it is concluded that Therefore, it can be concluded that there is a difference in problem-solving abilities between students with high motivation and those with low motivation regarding the topic of light waves in class XI at MAN 2 Model Medan.

3.6.3 Hyphothesis Test III

Hypothesis testing using Anova to see if there is a model, motivation on problem solving ability. Hypothesis testing was carried out using the Analysis of Variance technique (ANAVA) two-way test with the help of SPSS 25 software. The test criterion adopted is $F_{count} > F_{table}$ at the significance level $\propto = 0.05$, So the hypothesis is considered valid. The data processing results obtained are presented in the table below:

Table 10. Anava Test

Source	Type III Sum Of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1661,881[a]	3	553,960	24,483	,000	,527
Intercept	443787,086	1	443787.086	19613,890	,000	,997
LearningModel	316,210	1	316,210	13,975	,000	,175
StudentMotivation	1168,245	1	1168,245	51,632	,000	,439
LearningModel* StudentMotivation	101,760	1	101,760	4,497	,038	,064
Error	1493,327	66	22,626			
Total	485796,975	70				
Corrected Total	3155,207	69				

Based on the table above, it is obtained $F_{count}(AB) > F_{table}$ and sig. < 0.05, then H_0 is rejected, This indicates that there is an interaction between the TPACK-based differentiated inquiry learning model and student motivation.

3.7 Discussion

Based on the results of the research that has been done, there are differences in problem solving skills between students taught with TPACK-based differentiated inquiry learning models and controls after controlling for students' initial abilities. This supports research by Liliawati that The differentiated learning approach in the inquiry model can be one of the teacher's references to improve students' numeracy skills in physics or other subjects, because it is proven that there is an influence and improvement in numeracy skills when researchers conduct research [9]. From this explanation, it can be concluded that the TPACK-based differentiated inquiry learning model not only enhances students' problem-solving skills but also boosts their engagement in learning. This is supported by Aningsih & Irnawati Sapitri, who note that the inquiry learning model fosters students' curiosity about unfamiliar material, motivating them to seek answers independently. As a result, the inquiry learning model promotes student participation, positively impacting their learning outcomes [10].

The research findings indicate that there are differences in problem-solving skills between students with high motivation and those with low motivation, after accounting for their initial abilities. This is consistent with the research by Prawijaya, which suggests that low learning motivation leads to lower problem-solving abilities, whereas high learning motivation correlates with higher problem-solving skills [11]. The steps students take to solve problems should be accompanied by strong motivation to optimize their problem-solving skills. Additionally, Imron & Sahyar noted that motivation plays a crucial role in determining the effectiveness of learning in achieving goals. The higher the motivation, the greater the likelihood of success in learning, which subsequently enhances students' abilities [12].

There was also an interaction between the TPACK-based differentiated inquiry learning model and students' motivation. This interaction encourages greater student engagement and activity in the classroom, leading to improved problem-solving skills. The model necessitates that students actively participate in their learning groups, utilizing relevant technology. This aligns with research by Armys & Derliana, which suggests that students collaborating in study groups can effectively test hypotheses and develop new ones based on their problem-solving strategies and methods [13].

Similarly, in this study, the research instruments were meticulously designed to improve problem-solving abilities. The results show that the average problem-solving skills of students taught with the TPACK-based differentiated inquiry learning model are superior to those of students instructed through conventional methods. Furthermore, expert validation of all instruments, including the problem-solving ability test sheets and teaching modules, yielded positive feedback.

Acknowledgement

My special thanks to State University of Medan for the research funding given to me in 2024. I also thank the lecturers in the physics eduacation study program at the State University of Medan who helped me to complete this research.

Conclusion

The analysis of the data from the research findings indicates that there are differences in problem-solving abilities between students taught with the TPACK-based differentiated inquiry learning model and those who received conventional teaching, after considering their initial abilities. Moreover, a distinction exists in problem-solving skills between students with high motivation and those with low motivation, once again accounting for their initial abilities. Additionally, there is an interaction effect between the TPACK-based differentiated inquiry learning model and the motivation levels of students.

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