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The framework of Technological Pedagogical Content Knowledge on Chemistry Learning Tools Development

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Abstract

Electrolyte and nonelectrolyte solutions are chemical materials with three levels of representation, and they are materials that integrate scientific skill and conceptual understanding. However, there were still many learning difficulties during the learning process and caused the low students' science process skills. One of the factors that students experience difficulty learning was that teachers were not optimal in lesson planning. In fact, in achieving learning objectives, it was necessary to have optimal learning plans. One of the optimal learning plans was obtained by preparing learning instruments such as lesson plans and an electronic worksheet that integrated *TPACK*. This research is a descriptive study that aims to analyze the learning needs and descriptively the TPACK components and science process skill indicators in the developed chemistry learning tools. The data collection techniques in this study used document study, interviews, and surveys. The research subjects were students and teachers of class XI IPA SMA in Jambi City. This research could conclude that the learning needs to be analyzed needed *TPACK* Integrated in the developed chemistry learning tools. The second, this learning tool integrated Technology, Pedagogic, and Content Knowledge components, and it had science process skill indicators.

1. INTRODUCTION

Chemistry material is one of the senior high school learning materials, consisting of three levels of representation: the macroscopic level, the submicroscopic level, and the symbolic level. The macroscopic level is a phenomenon that can be observed in plain view, such as the physical properties and phenomena that occur in nature (Herawati, Mulyani, & Redjeki, 2013). The submicroscopic level is a phenomenon that cannot be observed with the naked eye, such as the particular movement of atoms of matter. At the same time, the symbolic level depicts the macroscopic and submicroscopic levels into a symbol, such as reaction equations and symbols of elements and compounds (Desyana & Melati, 2014).

The material of electrolyte and nonelectrolyte solutions is one of the chemical materials where there are three levels of representation that are widely available in everyday life. The movement of the particles can be observed, and there are chemical symbols so that the material is helpful for students or institutions that study it. However, in the learning process, there are still many learning difficulties. Wilandari's research explained that students of class X IPA SMA in Pandeglang Banten can explain a solution, provide examples for the solution appropriately, and identify solutes and solvents in a solution. However, most students think that the solution sugar and salt are electrolytes (Wilandari, Ridwan, & Rahmawati, 2018). Then another difficulty was found in the Medina study, where Padang City students in Senior High School experienced difficulties in understanding electrolyte and nonelectrolyte solution material on the concepts of ionic sounds, polar covalent compounds, and ionization. Students' wrong answers could be because students did not fully understand the concept of electrolytes in macro, micro, and symbolic terms (Medina, 2017).

One of the factors for students who have difficulty learning is that the teacher is not optimal in planning lessons. According to (Pane & Darwis Dasopang, 2017), learning is a process of interaction between a teacher and students with other learning resources to achieve the expected learning goals. Of course, in achieving learning objectives, it is necessary to design an appropriate learning plan. The material of electrolyte and nonelectrolyte solutions is a material that integrates scientific attitudes and conceptual understanding. This is called the science process skill (Suja, 2021). Learning tools are needed to improve students' science process skills by preparing instruments in the form of lesson plans and electronic worksheets that integrate Technological Pedagogic Content Knowledge (*TPACK*) to solve the problems. The *TPACK* framework integrates technology, pedagogy, and content in producing ICT-based learning (Mairisiska, Sutrisno, & Asrial, 2014).

Based on research conducted by (Hayati, Sutrisno, & Lukman, 2014), the *TPACK* integrated chemistry learning tool was proven to optimize students' Higher Order Thinking Skill on colloid material. Then according to (Gunawan, Sutrisno, & Muslim, 2020) where the *TPA*skillssed mathematics learning tool is able to optimize students' critical thinking skills in the material of the two-variable lin canon system. Researchers see benefits in development research in *TPACK*, which is to optimize students' learning skills. When viewed in the field of chemistry, *TPACK* learning is still rarely carried out, especially on electrolyte and nonelectrolyte solution material, so that researchers conduct development research on *TPACK*-based learning tools on these materials. However, the Researcher could not analyze the *TPACK* components to increase science process skills directly or indirectly using Path Analysis in this condition because the Covid-19 pandemic made it challenging to measure students' science process skills. So, the purpose of this research was (1) to analyze the learning needs; (2) to describe descriptively the *TPACK* components and science process skill's indicators contained in this development learning tools, so that this research was packaged under the title "*The framework of Technological Pedagogical Content Knowledge in chemistry learning tools development* "

2. METHOD

This research is descriptive research describing learning tools consisting of *TPACK* components .nd science process skill indicators; where to get it, the researchers need to analyze learning needs through several samples. Researchers use the purposive sampling method to determine research subjects. The research subjects are 30 students of class XI IPA and two SMAN 3 Jambi and SMAN 11 Jambi teachers. The types of data in this research are interviews, document studies, and questionnaires. Interviews were conducted using teacher interview sheet instruments, with measurement indicators by the 4D development research procedure by Thiagarajan (Mulyatiningsih, 2013), with the following description.

Table 1. Teacher Interview Sheet Grid

Aspect	Indicator
Learning Materials	Student's ability to understand learning
	Achieve The Cut Score
Students' Experience	Students' understanding of chemical representations
	Students' Attitudes (affective, cognitive, psychomotor)
	Student response to technology
Learning Activities in Electrolyte and Nonelectrolyte Solution Materials	Learning Model
	21st Century Skills
	Student interest in learning
	Student's motivation to study
	Students' learning styles
	Science Process Skills
Media Selection	Learning Tools
	Teaching materials
	Learning facilities and infrastructure

The data analysis technique used on the teacher's interview sheet was coding. According to Saldana, The coding technique is a way of obtaining words or phrases that stand out by capturing and marking the essence of facts that emerge strongly from several collections of language or visual data (Mahpur, 2017). The data can be in the form of interview transcripts.

The questionnaire instrument is in the form of a questionnaire on the student's needs and characteristics. The type of survey instrument is a closed questionnaire. The questionnaire instrument indicators of student needs and characteristics were adapted by Thiagrajan's 4D development research procedure (Mulyatiningsih, 2013), with the following description.

Table 2. The grid of analyzes students' needs and characteristics' questionnaire

Aspect	Indicator
Learning Materials	Students' understanding of Electrolyte and Nonelectrolyte Solution
	Learning difficulties in electrolyte and nonelectrolyte solutions
Students' Experience	Experience doing practicum
	Experience operating a laptop
Learning Activities in Electrolyte and Nonelectrolyte Solution Materials	Teacher studies chemistry outside of school hours
Media Selection	Solutions in understanding chemical materials
	Teaching materials
	Learning facilities and infrastructure

Then the data obtained from the questionnaire were analyzed using a rating scale (Eko Yulianto & Rohaeti, 2013), with the following formula.

$$\text{Observation results}'\text{Score} = \frac{\text{Obtained Score}}{\text{Maximum Score}} \times 100\% \quad (1)$$

Furthermore, the document studies in this researchers used previous articles that are related to this research. According to (Arikunto 2014), data analysis techniques in documentation studies are not complex. Researchers only look for variables that have been determined. If there are variables to be looking for, the Researcher just needs to record these things with free sentences. This is done by researchers in finding data in previous articles.

3. RESULTS AND DISCUSSION

Learning difficulties have caused students' scientific process skills not to be achieved optimally in studying electrolyte and nonelectrolyte solution materials. Analysis results are obtained based on related journals, teacher's interviews, and questionnaires for student characteristics requiring the development of TPACK-based learning tools.

Table 3. Identification of Low Science Process Skills Based on Research Problems

No.	Research Problems	Science Process Skills' Indicator
1.	Research by (Suari, Selamat, & Suja, 2018) said that the ethanol compound is classified as an electrolyte solution because it is dissolved in water and will break down into free molecules. Based on the Researcher's analysis, if students are right in gathering information, students can get the correct answers regarding the types of ethanol compound solutions. Then the students did not process the data well because, in the experiment, it was clear that the ethanol solution could not turn on the light. Based on this analysis, it is evident that students cannot collect information and process data correctly, so they cannot describe the relationship between the type of ethanol solution and the experiments that occur.	• Students cannot collect information, so students cannot answer correctly about the ethanol compound solution. • Students did not process the data well because, in the experiment, it was clear that the ethanol solution could not turn on the light. • Students cannot describe the relationship between the type of ethanol solution and the experiments that occur.
2.	Research by (Wilandari et al., 2018), students assume that the sugar and salt solutions are electrolytes; both sugar crystals and salt crystals, when dissolved in water, will break down into free ions. According to the Researcher, students cannot carry out and analyze research properly because it is clear that salt solution can turn on the lamp while sugar cannot turn on the light. Then students also cannot identify the properties of electrolyte and nonelectrolyte solutions. Students are challenged to describe the relationship between the electrolyte and nonelectrolyte solutions from a conceptual perspective with practice in the field. If	• Students cannot do research well because students who do research know that the salt solution can turn on the lamp while sugar cannot turn on the light. • Students cannot analyze research well because it is evident that salt solution can turn on the lamp while sugar cannot turn on the lamp. • Students cannot identify the properties of electrolyte and nonelectrolyte solutions during the practicum, • So that students find it challenging to describe the relationship between the nature of electrolyte and

	students make observational data tables properly, it can help identify the properties of the solution and describe the relationship between variables so that minor misconceptions occur.	nonelectrolyte solutions from a conceptual perspective with practice in the field. • Students do not make observational data tables properly, so that students have difficulty identifying the properties of the solution and describing the relationship between variables.
3.	Based on the results of interviews with chemistry teachers at SMAN 3 and SMAN 11 Jambi City, not all students were active in conducting experiments, let alone connecting observational data with actual concepts.	• Students are not active at the beginning of the lesson • Students do not integrate scientific skills and conceptual understanding
4.	Based on data analysis through a questionnaire on the needs and characteristics of class XI IPA high school students in the city of Jambi (SMAN 3 and SMAN 11), about 20 % of students did not know what type of solution was ethanol, 50 % answered that C_2H_5OH is an electrolyte solution because it is a polar compound. However, About 30 % of students understand the questions and types of electrolyte and nonelectrolyte solutions.	• Students cannot collect information, so students cannot answer correctly about the ethanol compound solution. • Students did not process the data well because, in the experiment, it was clear that the ethanol solution could not turn on the light. • Students cannot describe the relationship between the type of ethanol solution and the experiments that occur.

The data analysis from a questionnaire on the needs and characteristics of class XI IPA high school students in the city of Jambi (SMAN 3 and SMAN 11) can be seen as follows.

No	Aspect	Student Response XI IPA (30 Students)	Percentage (%)
1.	Are chemical materials challenging to study?		
	a. Yes	25	83,3 %
	b. No	5	16,6 %
2.	Is the teacher's explanation enough for you to understand chemistry material?		
	a. Yes	18	60 %
	b. No	12	40 %
3.	What kind of understanding difficulties do you often encounter when studying chemistry?		
	a. Understanding the Material Concept	4	13, 3 %
	b. The concept application of the matter to everyday life	10	33,3 %
	c. Understanding exercises	16	53,3 %
4.	What efforts did you and the teacher make to overcome your understanding?		
	a. Search in books	5	16,6 %
	b. Search in the internet	10	33,3 %
	c. Search in various literature	15	50 %
5.	What do you hope that the difficulty of understanding chemistry can be adequately resolved?		
	a. There are learning support books	2	6,66 %
	b. There is a complete learning media about chemistry (LKPD with an attractive appearance containing explanations of material including photos, videos, animations, and question exercises)	25	83,3 %
	c. Get more practice exercises	3	10 %
6.	Have you ever practiced electrolyte and nonelectrolyte solutions?		
	a. Yes	30	100 %
	b. No	–	–
7.	Are electrolyte and nonelectrolyte solution materials inappropriate material?		
	a. Yes	11	36,6 %
	b. No	19	63,3 %
8.	Give the correct answer to the following question. Based on the experimental data below, which is the electrolyte and nonelectrolyte solution? Give your argument!		

No.	Sample	Substance Formula	Lamp Lights
1.	Distilled water	H_2O	No flame
2.	Sulfuric acid solution 1M	H_2SO_4	Lights up brightly
3.	Ammonium Chloride Solution 1M	NH_4Cl	Dimly lit
4.	Sugar solution 1M	$C_{12}H_{22}O_{11}$	No flame
5.	Sodium Chloride	NaCl	Lights up brightly

	Solution 1M		
	a. Answered and correct	25	83,3 %
	b. Answered and wrong	4	13,3 %
	c. No answer	1	3,33 %
9.	Polar covalent compounds can also partly form vital electrolytes, and some can form weak electrolytes. C_2H_5OH is a polar covalent compound. In your opinion, what type of solution does C_2H_5OH belong to? Give your argument!		
	a. Answered and correct	9	30 %
	b. Answered and wrong	15	50 %
	c. No answer	6	20 %
10.	Consider the following reaction. $NaCl(aq) \rightarrow Na^+(aq) + Cl^-(aq)$ $CH_3COOH(aq) \leftrightarrow CH_3COO^-(aq) + H^+(aq)$ $C_2H_5OH(aq) \rightarrow 2C + 3H_2 + ½O_2$ Which is an electrolyte compound and can conduct electricity? Give your argument!		
	a. Answered and correct	13	43,3 %
	b. Answered and wrong	10	33,3 %
	c. No answer	7	23,3 %
11.	Do you re-learn chemistry outside of school hours?		
	a. Yes	18	60 %
	b. No	12	40 %
12.	How do you study chemistry outside of school hours?		
	a. Learn from Book	14	46,6 %
	b. Learn from the internet	7	23,3 %
	c. Learn from literature	9	30 %
13.	Can you use a computer/laptop?		
	a. Yes	29	96,6 %
	b. No	1	3,33 %
14.	Do you have a computer/laptop?		
	a. Yes	25	83,3 %
	b. No	5	16,6 %
15.	Do you have a smartphone/tablet (Android, IOS (iPhone), Windows Phones, etc.)?		
	a. Yes	30	100 %
	b. No	–	–
16.	Is there a computer laboratory in the school?		
	a. Yes	30	100 %
	b. Nothing	–	–
17.	Are LCD / Infocus facilities available at school?		
	a. Yes	30	100 %
	b. Nothing	–	–
18.	Has your chemistry teacher ever used media such as power points and virtual labs in learning?		
	a. Yes	30	100 %
	b. No	–	–

Based on the problems in the two tables above, science process skills are still low. So that, researchers want to develop TPACK-based learning tools on electrolyte and nonelectrolyte solution material. However, The research implementation was only at the learning need analysis step because of COVID 19. Then the Researcher described descriptively the TPACK components and science process skill indicators contained in the learning tools. The descriptive analysis process begins by knowing the problems contained in the electrolyte and nonelectrolyte solution material, then identifying and categorizing indicators of low science process skills on these problems, then analyzing what technology can solve the problem, and analyzing what learning models can convey messages learning the material, with the following reviews. Indicators of low student science process skills, projected into Competency achievement indicators, are described as follows.

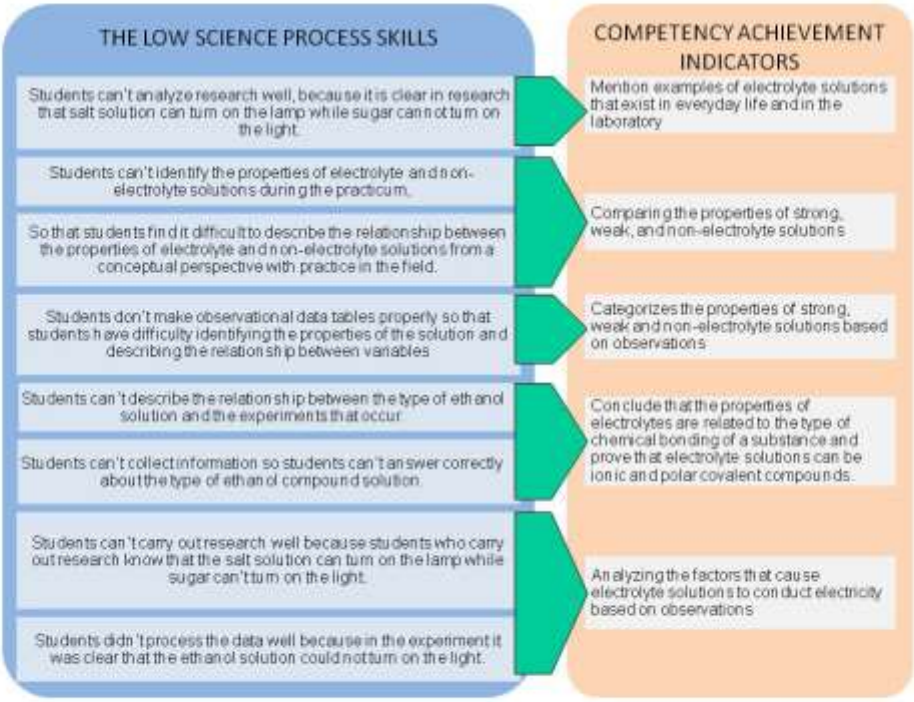

Figure 1. Identification of Competency Achievement Indicators Based on Low Science Process Skills

Based on research by (Mairisiska et al., 2014) said that through the development of TPACK-based learning tools, students' critical thinking skills were categorized as good. Hence, the component that significantly affected was Technology Content Knowledge (0.529), so that researchers analyzed what technology could solve the problem of low science process skills, with the following description.

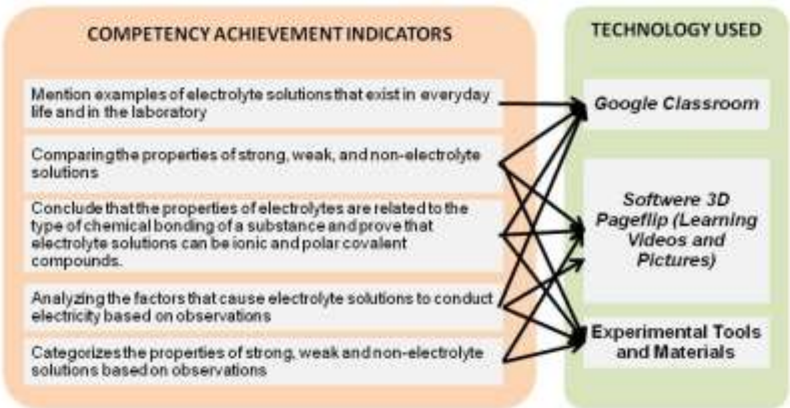

Figure 2. Identification of Technology Used Based on Competency Achievement Indicators

Based on the description of the image above, the Competency Achievement Indicators are referred to as Content Knowledge, and the technology used is referred to as Technology Knowledge, which can be concluded in a slice of the TPACK framework between Technology Knowledge and Pedagogic Knowledge as follows.

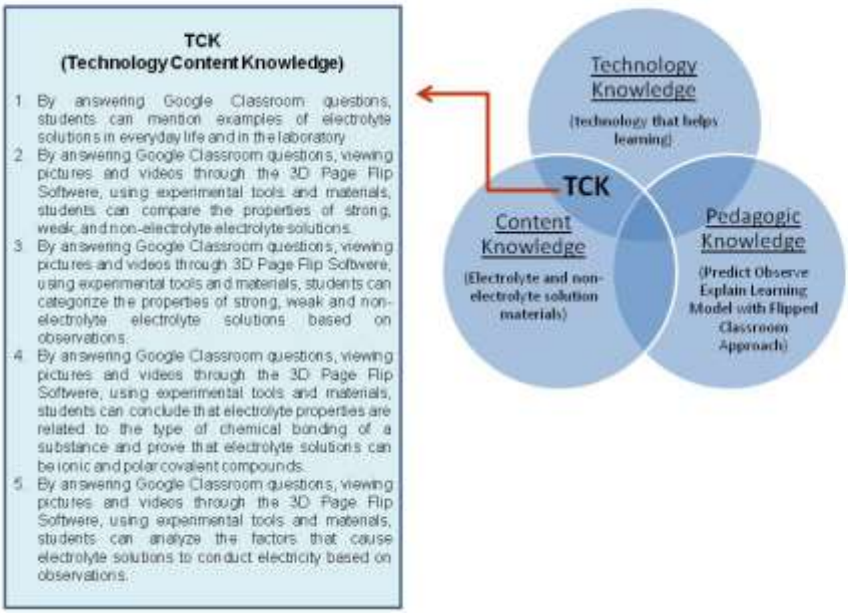

Figure 3. Technology Content Knowledge Framework (TCK)

The important thing in developing TPACK-based learning tools is a learning model (Pedagogic Knowledge) in delivering the material because, according to (Gunawan et al., 2020), TPACK components that have an effect are PCK (0.354) and PK (0.367) so that students' critical thinking skills fall into the outstanding category. Then the learning model that can optimize science process skills, according to (Nurlaili, Bakar, & Afrida, 2019), is the Predict Observe Explain learning model. In their research, at the beginning of student learning is not too active. Hence, researchers combine it with the flipped classroom approach, because according to (Nouri 2016), flipped classrooms can make active learning time-efficient and increase the low learning achievement so that if a slice of Content Knowledge is made with the Predict Observe Explain learning model with the Flipped Classroom (Pedagogic Knowledge) approach, a slice of the TPACK framework is obtained as follows.

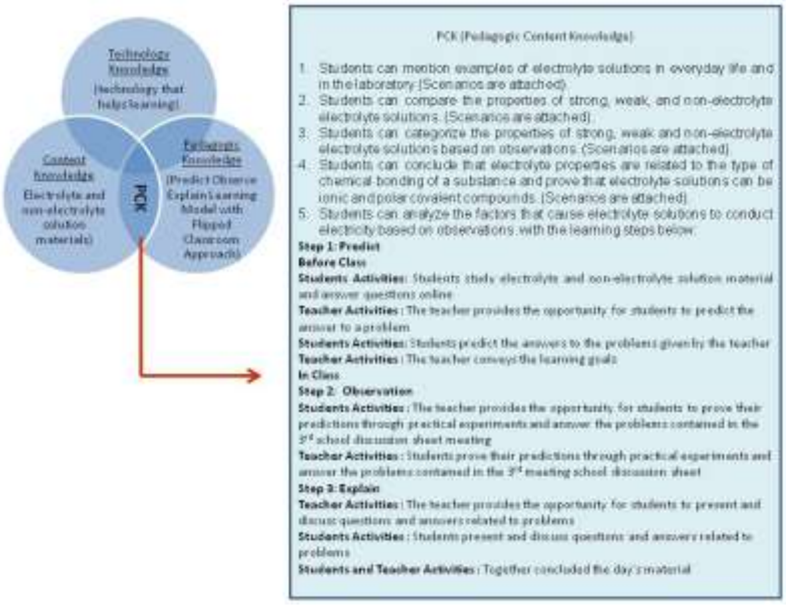

Figure 4. Pedagogic Content Knowledge Framework (PCK)

The problem in this study is that students' misconceptions are caused by students' lack of understanding from a submicroscopic point of view; students' misconceptions lead to soft science process skills, so students need technology in projecting the electrolyte and nonelectrolyte solution material so that learning can be conveyed, but in delivering the material and technology requires an appropriate

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strategy so that the material can reach the recipient, so a learning model is needed to package the suitable material and technology to convey the message of learning. In addition to the proven success of the Predict Observe Explain Model in optimizing science process skills through previous journals, the selection of the Predict Observe Explain Model with the Flipped Classroom approach is also following electrolyte and nonelectrolyte solution materials using practicum and understanding concepts, according to (Warsono & Hariyanto, 2012) The Predict Observe Explain model motivates for students to investigate concepts that have not been understood to prove the prediction results. So, when students have not started practicum, students have predicted concepts that have not been understood in the form of practicum results. There is a process of integrating scientific skills and understanding concepts and students are also more motivated. Then to project abstract material, learning models, and materials combined with technology so that learning messages can be conveyed.

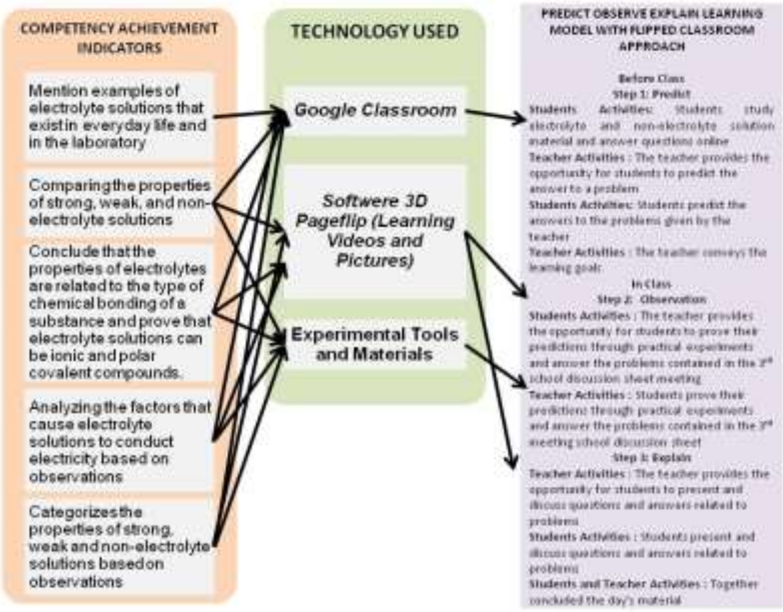

Figure 5. The linkage scheme between TPACK components

The following is an example of a product from the TPACK-based learning tool developed by researchers, where Technology Knowledge is in the form of 3D page flip software, Google Classroom, experimental tools, and materials; Content Knowledge, comparing the properties of strong, weak, and nonelectrolyte solutions based on observations; Pedagogic Knowledge in the form of Lesson Plan in Predict Observe Explain Learning with the Flipped Classroom approach.

Table 4. The results of the descriptive analysis of TPACK-based learning tools

Flipped Classroom Approach/ Learning Step	Teacher and Students' activities	Emerging Indicators of Science Process Skills	Technology Used
Before Class/ Predict Step	Students: Students open e-LKPD and watch videos presented by the teacher in e-LKPD. Videos that contain materials such as the concept of electrolyte and nonelectrolyte solutions, electrolyte solutions can be ionic and polar covalent compounds, and test the electrical conductivity using an avometer	–	3D Page flip (The figure of Product at Figure 6)
	Students: Work on the 2nd meeting house assignment sheet in e-LKPD online by opening google classroom, then students are expected to ask questions related to material that is not understood, and questions are written in the comments column of the 2nd meeting house assignment sheet (google classroom), Other students expected to answer questions raised by fellow students.	• Collect and process data • Identifying variables	• 3D Page flip, • Google Classroom (The figure of Product at Figure 7)
	Teacher: In google classroom, the teacher provides	• Identifying	3D Page flip

	opportunities for students to predict the answer to a problem "Presented several solutions such as salt solution, lime solution, 1M NaOH solution, 1M HCl solution, battery solution, kitchen vinegar solution, Batanghari river water, which one is classified as a robust electrolyte solution and a weak electrolyte? "	variables, • Creating Hypotheses	
	Students: Students predict the answers to the problems given by the teacher.		
In-Class/ Observation Step	Teacher: The teacher provides opportunities for students to prove their predictions through practical experiments and opens the 2nd school discussion sheet meeting as a reference	• Design research • Do a research	• 3D Page flip, • Experimental Tools and Materials
	Students: Students and learning groups prepare experimental samples neatly and correctly. Students and their learning group conduct practical experiments on the properties of electrolyte solutions and nonelectrolyte solutions, observe and record observations with accurate results.		
	Teacher: The teacher provides opportunities for students to prove their predictions by answering the problems contained in the 2nd school meeting discussion sheet	• Creating hypothesis, • Identifying variables, • Create data tabulations, • Collect and process data, • Analyze Research • Describe the relationship between variables	• 3D Page flip, • Experimental Tools and Materials
	Students: Students and their learning group collect and process the data obtained from the observation results then the observation data is used to answer the problem.		
In-Class/ Explain Step	Teacher: The teacher provides opportunities for group representatives to conclude and present the results of the experiment as well as the results of the discussion (by reading the answers to the problems on the 2nd school discussion sheet meeting)	• Collect and process data, • Defining variables operationally	3D Page flip
	Students: Students conclude and present the results of the experiment as well as the results of the discussion (by reading the answers to the problems on the 2nd school discussion sheet meeting)		
	Teacher: The teacher provides opportunities for students to refute the opinions of other groups in order to get actual statements		
	Students: Students between groups mutually argue the opinions of other groups in order to get the accurate statement		
	Teacher: The teacher guides students in making conclusions.		
	Students: Students can conclude the difference in the properties of solid electrolyte solutions and weak electrolytes, categories of the solid electrolyte and weak electrolyte solutions based on observations, that electrolyte properties are related to the type of chemical bonding of a substance and prove that electrolyte solutions can be ionic and polar covalent compounds.		

An example of the relationship between Content Knowledge, Pedagogic Knowledge, and Technology Knowledge is evidenced by the product image described in table 2, with the following reviews.

Figure 6. Student activities use 3D Page flip to study the material of electrolyte and nonelectrolyte solutions

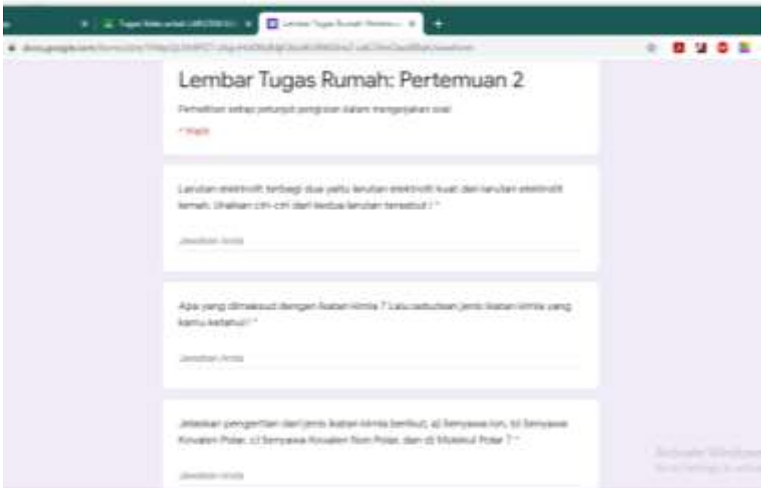

Figure 7. Student activities use 3D Page flip to answer questions online

Based on the description above, the learning tools consist of Technological Pedagogical Content Knowledge (*TPACK*) components, where technology is an electronic worksheet, pedagogical is Predict-Observe-Explain learning model with the flipped classroom approach, content is the electrolyte and nonelectrolyte solution materials, Then learning tools such as e-Worksheet and lesson plan have science process skills' indicators. According to (Sitompul, Setiawan, & Purba, 2017), *TPACK*-based learning tools development improves learning achievement. Then according to (Waluyo & Nuraini, 2021), the TPACK-based instructional learning development can increase problem-solving ability. TPACK has a vital role as a provision for teachers in learning Islamic education. By understanding TPACK, Islamic education teachers can present innovative and creative learning and effective in the classroom so that students easily understand the ongoing learning (Ajizah & Huda, 2020). Based on the previous research journals, *the TPACK* framework has the potential to increase learning ability. The Researcher hopes another researcher could be continued this research and analysis in more detail about the analysis of TPACK in learning tools, analysis of science process skills that appear in using the learning tools, and The TPACK-based learning tools can increase the science process skills.

4. CONCLUSION

This study aims to analyze the observation result through data collection instruments in previous research journals, teacher interviews, and Questionnaires for Students' Needs and Characteristics. It concluded to need the *TPACK*-based learning tools development. Then the learning tools will develop were to consist of Technological Pedagogical Content Knowledge (*TPACK*) components, where technology is an electronic worksheet, pedagogical is Predict-Observe-Explain learning model with the flipped classroom approach, content is the electrolyte and nonelectrolyte solution materials, The learning tools such as e-Worksheet and lesson plan have science process skills' indicators.

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