DEVELOPMENT OF TPACK'S INTEGRATED PROBLEM-BASED LEARNING TOOL TO IMPROVE SCIENCE LITERACY AND PROBLEM-SOLVING SKILLS OF STUDENTS ON GLOBAL WARMING MATERIALS

THESIS

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UNIVERSITAS NEGERI SURABAYA

POSTGRADUATE

STUDY PROGRAM OF SCIENCE EDUCATION

2023

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THESIS

Submitted to Universitas Negeri Surabaya Postgraduate Program to Fulfill Part of the Requirements in Obtaining a Master of Education Degree in the Science Education Study Program

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APPROVAL

Thesis on behalf of Hasan Nuurul Hidaayatullaah, NIM 20070795011, with the title "Development of TPACK Integrated Problem Based Learning Tool to Improve Students' Scientific Literacy and Problem-Solving Skills on Global Warming Material" has fulfilled the requirements and approved to be tested

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hereby declares that the thesis entitled "Development of TPACK Integrated Problem-Based Learning Devices to Improve Students' Scientific Literacy and Problem-Solving Skills on Global Warming Material" is my own work and is not the result of plagiarism.

Thus I made this statement letter truthfully. If in the future it is proven/can be proven that this thesis is plagiarized, I am willing to bear all the consequences.

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ABSTRACT

Hidaayatullaah, Hasan Nuurul. 2022. *Development of TPACK's Integrated Problem Based Learning Tool to Improve Science Literacy and Problem-Solving Skills of Students on Global Warming Materials*. **Thesis,** Science Education Program, Postgraduate Program State of Universitas Negeri Surabaya. Supervisors: (I) Prof. Nadi Suprapto, M.Pd., Ph.D and (II) Dr. Eko Hariyono, M.Pd.

Keywords: Learning Tools, Problem-based learning, TPACK, Science Literacy Skills, Problem Solving Skills, Physics.

This study aims to produce learning tools to improve students' scientific literacy and problem-solving skills on global warming in Senior High School. The development of these learning tools used the 4-D development model (define, design, develop, and disseminate). Research on the development of learning tools was carried out at the Unesa Postgraduate Program and the implementation phase was carried out at state Islamic High School 2 Lamongan. The research instrument used is the assessment of validity, practicality, and effectiveness. Data collection techniques include validation, observation, test sheets, and questionnaires. Research data were analyzed in a quantitative descriptive manner. The results obtained are (1) the learning tools that have been developed are declared valid in terms of content, presentation, and language criteria; (2) the learning tools developed are stated to be practical in terms of (i) the level of implementation of learning is classified as good and very good, (ii) the activities of students are classified as good and very good, and (iii) the obstacles encountered in learning can be overcome so that the learning process can be achieve the expected goals; (3) the learning device was declared effective because it could improve students' scientific literacy and problem-solving skills with an increase in the high category with consecutive N-gain values of 0.75 and 0.70, and obtained very good responses from research subjects. Thus it can be concluded that the learning tools that have been developed are declared feasible to improve students' scientific literacy and problem solving skills.

PREFACE

Praise be to Allah SWT, the Lord of the worlds because of His grace, mercy, grace, guidance, and blessing so that the author can complete the thesis with the title "Development of TPACK Integrated Problem Based Learning Learning Devices to Improve Scientific Literacy and Problem Solving Skills of Students at Global Warming Material”. This thesis was prepared with the aim of fulfilling one of the prerequisites for obtaining a Master of Science Education degree. During the preparation of this thesis, the writer always received guidance and support from various parties. Therefore, the author would like to thank:

1. Prof. Nadi Suprapto, S.Pd., M.Pd., Ph.D. as Supervisor I who always provides guidance, direction, enthusiasm, inspiration, advice, and motivation during the writing of this thesis.
2. Dr. Eko Hariyono, S.Pd., M.Pd. as Supervisor II and Head of Master of Science Education Study Program, Postgraduate, Surabaya State University who always provides guidance, enthusiasm, and motivation so that the preparation of this thesis can be completed properly.
3. Prof. Tjipto Prastowo, Ph.D., Beni Setiawan, Ph.D., and Dr. Titin Sunarti, M.Sc. as Examining Lecturer who is willing to provide input, suggestions, and guidance in writing this thesis.
4. Prof. Tjipto Prastowo, Ph.D., Dr. Binar Kurnia Prahani, M.Si., and Dr. Titin Sunarti, M.Sc. as a validator lecturer who has agreed to provide input, suggestions, assistance, and guidance in developing learning tools.
5. Prof. Dr. Wasis, M.Sc. as Postgraduate Director, State University of Surabaya.
6. Prof. Dr. Madlazim, M.Sc. as Dean of the Faculty of Mathematics and Natural Sciences, Surabaya State University.
7. Purnomo, S.Pd., M.Pd. as the principal of Madrasah Aliyah Negeri 2 Lamongan who is willing to accept me to do research at the MAN 2 Lamongan school.

8. Nurul Masfufah, S.Pd., M.Pd. and Fatmiany, S.Pd., M.Pd. as the physics teacher at MAN 2 Lamongan who is willing to help in data collection.
9. My father, mother, and brothers who always accompany me, provide support, motivation, and always pray for me.
10. My friends who helped during the trial implementation of this research.
11. All parties who helped in the preparation of this thesis.

May Allah SWT always repay the good deeds that have been done. The author hopes that this thesis can be useful for all of us, especially for the development of education in this beloved country of Indonesia, Aamiin.

Surabaya, December 2022

Author

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
INTRODUCTION

A. Background

Environmental problems are one of the biggest challenges faced by humans today. Global warming has been triggered and accelerated by the increasing severity of natural disasters. As a result, not only do catastrophic events occur repeatedly, but also the weather becomes a challenge to anticipate. Humans are undoubtedly the main contributor to this alarming state of nature (De Cieri et al., 2017; Kweku et al., 2018; Zandalinas et al., 2021). But in fact, ignoring nature seems to have become a lifestyle for most people today. In a book entitled Climate Science Special Report, written by a team from the National Science Foundation and U.S. The Global Change Research Program states that human activity is the main driver of the recent rise in global temperatures compared to natural processes (Wuebbles, 2021).

One of the factors that is predicted to cause a lack of public awareness in reducing the effects of global warming is the low knowledge and skills of the community in efforts to tackle global warming (Arshad et al., 2020; Urbańska et al., 2022). Therefore, students as the younger generation must be able to master scientific literacy and problem-solving skills. With these skills, students will be able to contribute in efforts to minimize the impact of global warming and be able to explain phenomena around them to the public so they can have a wise attitude towards the environment. On the other hand, scientific literacy and problem solving skills are also one of the 21st century skills that must be possessed and mastered by students in today's modern era (Hidaayatullaah et al., 2020, 2021).

Scientific literacy is a person's capacity to use their knowledge to solve problems, learn new information, explain scientific phenomena, and draw conclusions based on evidence related to scientific issues (Suprapto et al., 2022; Widodo et al., 2020). Students' understanding of the environment, health, economy, modern society, and technology all depend on their level of scientific literacy. Conversely, a person's basic ability to solve a problem through critical, logical, and systematic thinking is known as problem solving skills. Problem solving skills are also a person's high-level thinking process to solve a problem by involving experience, understanding, and knowledge possessed (Gustia et al., 2019; Mahanal et al., 2022). Both abilities emphasize the importance of thinking and acting skills, which require mastery of thinking and the application of the scientific method to identify and solve social problems.

However, the fact is that students' scientific literacy and problem solving skills in the field are not as expected because they are still in the low category. This can be seen from the findings of the PISA (Program for International Student Assessment) study that Indonesian students were still in the low category from 2000 to 2018 because their scores were still below the average PISA mastery score (OECD, 2019). The low ranking of students in PISA is also due to their weak high-level problem-solving abilities. This shows that students have not been able to understand the concepts and processes of science and have not been able to apply the knowledge they have learned in everyday life (Bahri et al., 2021; Merta et al., 2020).

The low scientific literacy and problem solving skills of students are caused by several factors, one of which is an inappropriate learning model. Triwahyuni et al. (2020) also revealed that student achievement will be influenced by the selection of a learning model that is appropriate to the circumstances. In order for students to achieve the best possible learning outcomes, the success of the learning process does not only depend on the teacher's ability to use the right learning model but also on a comfortable learning environment and an innovative learning process (Ahied et al., 2020; Hariyono et al., 2021). Innovative learning that is packaged by the teacher is a method that is seen as capable of facilitating students so that they get progress in every process and learning outcome with the aim of creating fun learning so that the desired learning objectives are achieved (Saepuzaman et al., 2021).

One way to overcome the above problems is by implementing a problem-based learning (PBL) model. Learning by applying the PBL model can improve students' scientific literacy skills (Alatas & Fauziah, 2020) and problem solving

(Hidaayatullah et al., 2020; Sinensis et al., 2021). Siregar et al. (2022) states that if PBL is applied in learning, it will make learning more meaningful and student learning outcomes can experience classical mastery. PBL is a learning model that is triggered by problems, which can encourage students to learn and work cooperatively in groups to identify problems, think critically and analyze, be able to apply and use appropriate learning data sources to find solutions. The advantage of the PBL model is that students will be trained in scientific literacy skills and have the skills to solve problems they will encounter in everyday life so that learning is more meaningful (Setyarini et al., 2021; Tanti et al., 2021).

In addition, the learning approach also needs to be updated to achieve learning objectives and reduce obstacles in its implementation. One way to do this is to integrate Technological Pedagogical and Content Knowledge (TPACK) into learning. TPACK is a learning approach that is very relevant in the current technological era of learning (Chai et al., 2020; Lai et al., 2022). The teacher's ability to master technology in the learning process can be seen through the TPACK they have. TPACK is a theoretical framework for integrating technology, pedagogy, and subject matter in learning. The importance of TPACK integrated learning as information will concentrate on how technology can be tailor-made to address pedagogical needs to teach relevant content in certain circumstances (Nursyifa et al., 2020; Oktasari et al., 2020).

Based on the results of previous research conducted by Wardani & Jatmiko (2021) stated that TPACK-based physics learning with the PBL model is effective in increasing students' critical thinking skills. Chaidam & Poonputta (2022) in their research also stated that the results of learning mathematics after using PBL with the TPACK model were significantly higher than before using this model. Overall student satisfaction is also in the high category. TPACK-based learning is effectively implemented in physics learning activities and can improve HOTS and students' scientific attitudes (Ilmi et al., 2020). The demands of learning in the current industrial era 4.0 have an impact on innovative learning, learning designs with the TPACK framework can provide a useful framework for teachers to integrate technology in learning activities (Oktasari et al., 2020).

Based on the description above and support from previous research, the researcher intends to conduct research with the title "Development of TPACK Integrated Problem-Based Learning Tools to Improve Students' Scientific Literacy and Problem Solving Skills in Global Warming Materials". The urgency of this research is due to the lack of research and references for physics teachers in improving students' scientific literacy and problem solving skills through the development of problem-based learning integrated TPACK model learning tools. The purpose of this research is to produce appropriate learning tools.

B. Problem Statement

Based on the background description above, the problem in this study can be formulated, namely "How is the feasibility of the TPACK integrated Problem-Based Learning model learning tool in improving scientific literacy skills and problem solving for high school students?" The formulation of the problem can be described as follows:

1. What is the validity of the TPACK integrated problem-based learning tool to improve students' scientific literacy and problem-solving skills?
2. How practical is the TPACK integrated problem-based learning tool to improve students' scientific literacy and problem-solving skills?
3. What is the effectiveness of the TPACK integrated problem-based learning tool to improve students' scientific literacy and problem-solving skills?

C. Research Purposes

The purpose of this study was to produce a proper (valid, practical, and effective) integrated TPACK Problem-Based Learning model learning tool in improving the scientific literacy and problem-solving skills of high school students. From these general objectives can be broken down into specific objectives as follows:

1. Describe the validity of learning tools that have been developed based on expert judgment.
2. Describe the practicality of learning tools that have been developed, based on:

a. Implementation of learning by using learning tools that have been developed.
b. Student activities while participating in learning using learning tools that have been developed.
c. The obstacles encountered during the implementation of learning by using learning tools that have been developed.

3. Describe the effectiveness of learning tools that have been developed, based on:
   a. Students' scientific literacy skills after participating in learning with learning tools that have been developed.
   b. Students' problem-solving skills after participating in learning with learning tools that have been developed.
   c. Responses of students after participating in learning with learning tools that have been developed.

D. Benefits of research

In line with the objectives to be achieved, this research is expected to improve or improve the quality of physics learning in high school, especially those related to scientific literacy or problem solving. In addition, the research benefits obtained from the results of this study are as follows:

1) For Researchers

Can increase knowledge, insight, and mastery of learning by implementing problem-based learning tools with the TPACK approach.

2) For Schools

It is hoped that student achievement will increase so that the quality and quality of education in schools will also increase.

3) For Teachers

Assist teachers in considering effective learning strategies and can facilitate classroom learning to train students' scientific literacy and problem solving skills.

4) For Students

Can increase activity in the learning process and can improve scientific literacy skills and solving physics problems.

E. Limitations of Research

In order to obtain accurate and valid data as well as research that can be focused and directed, it is necessary to limit the scope of the research. The limits of this research include:

1. The developed learning tools focus on global warming material for Physics subjects in high school.
2. The thinking skills trained in this research are scientific literacy and problem solving.
3. The research was conducted on students of class X MAN 2 Lamongan

F. Assumptions of Research

In conducting this research, researchers assume that:

1. The validator team provides an assessment of learning tools that are developed objectively.
2. Students fill out research instruments honestly and seriously.
3. Students' pre-test and post-test results describe students' scientific literacy and problem-solving skills.
4. The observer fills in the observation sheet truthfully according to the conditions observed, without being influenced by other people.

G. Definition of Terms

In order to avoid differences in interpretation or perception of the terms used, the researcher provides the following definitions of terms:

1. Learning Tools

Learning tools are learning resources consisting of Syllabus components, Learning Implementation Plans, Handouts, Student Worksheets, and Evaluation Sheets.

2. ***Problem-Based Learning* (PBL)**

   The Problem-Based Learning model presents various contextual problems for students to use as learning resources and tools in an effort to help them improve their thinking skills without ignoring the knowledge or concepts that are the learning objectives. (Sani & Hayati, 2018; Setyo et al., 2020).

3. **The TPACK approach**

   The TPACK framework describes the knowledge a teacher needs to simplify pedagogical practices and understand concepts by incorporating technology into the classroom (Misra, 2016).

4. **Science Literacy Skills**

   Scientific literacy is an individual's understanding of concepts, phenomena, scientific processes, and drawing conclusions based on facts to engage and care about issues related to science (OECD, 2019).

5. **Problem Solving**

   The process of finding, selecting, and implementing a solution to a problem is known as problem solving. This process involves a number of steps, the first of which is to determine the root cause of the problem. The ability to solve problems that require critical, logical, and systematic thinking is referred to as problem solving skills (Hesse et al., 2015).

CHAPTER II
LITERATURE REVIEW

A. Learning Tools

Various means and media used by teachers and students to carry out the learning process are known as learning tools, and must be prepared before the implementation of learning. (Rahayu, 2020). Based on the rules related to standard and secondary learning processes in Permendikbud Number 65 of 2013 it is explained, the arrangement of learning tools includes learning planning which includes: learning scenarios, assessment tools, learning resources, media, syllabus, and Learning Implementation Plans (RPP). So in this regard, learning tools have a very significant position in the success of the teaching and learning process (Mahlianurrahman, 2020).

Based on the definitions presented by experts and the Minister of Education and Culture, it can be concluded that learning tools are a number of suggestions or media that students or students use in learning activities in class as an important tool to support the learning process so that it can run efficiently and effectively.

a) Syllabus

The definition of syllabus is explained in Government Regulation no. 13 of 2015. Syllabus is a lesson plan for a particular subject or topic that includes time allocation, learning resources, Core Competencies, Basic Competencies, learning materials, activities, and assessments. The syllabus is also defined as a reference for preparing a learning framework for each subject or theme study material developed based on the Graduate Competency Standards and Content Standards for primary to secondary education units according to the learning pattern in each particular academic year (Laily, 2022; Rahayu, 2020).

b) Learning Implementation Plan

Face-to-face learning activity plans for one or more meetings are known as lesson plans. Based on the syllabus, lesson plans are made to direct student learning activities in order to achieve Basic Competency (KD). According to the Minister of Education and Culture No. 22 of 2016 concerning process standards for primary and secondary education, the RPP component consists of the name of the education unit and school identity; subject or theme or sub-theme identity; class/semester; subject matter; Time Allocation; learning objectives; Learning Resources; learning methods; Learning Resources; take steps; assessment of learning outcomes (Makhrus, 2018; Rahayu, 2020).

c) *Handout*

All types of materials to assist teachers in learning are called handouts. In order for students to master all competencies as a whole and in an integrated manner, handouts can help them learn coherently and systematically. The material needed for basic competence is included in the handout. Handouts given to students must be in accordance with the material to be studied and the learning objectives to be achieved. A good handout is a textbook that meets the criteria of being accurate, appropriate (relevance), communicative, comprehensive and student-centered (Fahrurrozi and Mohzana, 2020).

d) Student Worksheets

Based on the 2013 curriculum, there was a change in the name LKS (Student Worksheet) to Student Worksheet (LKPD). One of the learning resources that can act as a facilitator in teaching and learning activities (teachers) is LKPD. LKPD in its preparation can be developed and designed according to the situation and conditions of the educational activities experienced. LKPD also includes learning media, because it can be used simultaneously with learning media or other learning resources. LKPD can be learning media and learning resources, depending on the activities designed (Dermawati et al., 2019).

In addition, LKPD also includes teaching materials that are used as guidelines for solving or investigating problems. LKPD can be in the form of training guidelines for developing cognitive aspects or can be guidelines for developing other aspects of learning, where through these LKPD it is hoped that they can train students' biological representation abilities and can also be used as another way of learning media.

e) Lembar Evaluasi (LE)

Evaluation, according to the Big Indonesian Dictionary, is an assessment. The process of providing information about the extent to which a learning activity has been achieved, how achievement is compared with certain standards to determine whether there are differences between the two, and how the benefits achieved compared to the goals to be achieved are all aspects of evaluation.

f) Assessment Instrument

The assessment instrument is a collection of instruments, both tests and non-tests, in which there are grids, instrument validity test results, instrument validation results, instrument scoring rubrics whose function is to measure the achievement of indicators and learning objectives (Dermawati et al., 2019).

B. Problem-Based Learning Model

1. Definition of Problem-Based Learning

Problem-Based Learning (PBL) is a learning model that can help students to improve the skills needed in the current era of globalization. According to Rusman (2013) suggests that Problem-Based Learning is a learning approach that is used to stimulate high-order thinking of students in situations oriented to real-world problems, including learning how to learn. PBL is also an innovation in education because it allows students to empower, hone, test and develop their thinking skills on an ongoing basis. This allows students to truly optimize their thinking skills through group or team work processes (Amir, 2016; Arie et al., 2020).

Problems in the curriculum require students to acquire important knowledge, become proficient in problem solving, develop their own learning strategies, and be able to work in teams. A systemic approach is used in the learning process to solve problems and challenges in everyday life (Hidaayatullah et al., 2020; Tanti et al., 2021). From some of the descriptions regarding the definition of Problem-Based Learning (PBL) above, it can be concluded that PBL is a learning model that presents various real-world problems, students are used as learning resources and tools to provide experience in improving their thinking skills without putting aside knowledge or concept that becomes the goal of learning.

2. Characteristics of the Problem-Based Learning Model

Each learning model has special characteristics or can be referred to as its own characteristics. Likewise, the PBL model has characteristics that distinguish it from other learning models, even though they are both problem-based. Ngalimun (2013) stated that there are 6 characteristics of the PBL model, namely:

a) The learning process begins with presenting the problem.
b) The problems presented relate to the real world of students.
c) Organize lessons around problems, not about disciplines.
d) Giving great responsibility to learners in shaping and directly carrying out their own learning process.
e) Using small groups.
f) Demand learning to demonstrate what they have learned in the form of a product or performance.

From the explanation above it can be concluded that the problem-based learning model emphasizes or is centered on students because to start learning, students are faced with problems in the real world. By using the PBL model, teachers present problems, ask questions, lead discussions, help students find problems, provide learning space, and focus on helping students develop their thinking skills.

3. Phases or PBL Model Syntax

The syntax or stages of problem-based learning are (1) the orientation of students on problems; (2) Organizing students' learning; (3) Guiding individual and group investigations; (4) Develop and present works; (5) Analyze and evaluate the problem-solving process (Arends, 2012). Teacher activities based on problem-based learning syntax are shown in Table 2.1.

Table 2. 1. Problem-Based Learning (PBL) Syntax

No	Phases	Teacher's Behavior
1	Phase 1: Conduct problem orientation to students	Teachers motivate students to participate in learning activities and communicate learning objectives. The teacher presents a problem and

No	Phases	Teacher's Behavior
		then students recognize the problem. The problems given can arouse students' interest and arouse their curiosity.
2	Phase 2: Organizing students to learn	The teacher assists students in defining and managing tasks related to problems, as well as determining the type of information needed to find solutions. To develop social skills and learn how to work together, students are directed to study in groups. Both teachers and students need to make good use of their time finding specific subtopics and conducting investigations.
3	Phase 3: Guiding the research group	Teachers encourage students to look for appropriate references by reading books, articles, or online sources to create and build ideas and make hypotheses. Then do experiments to solve the problem. The teacher observes the activeness of students in investigations and reviews solutions that can be applied to these problems. .
4	Phase 4: Develop and present the work	Teachers assist students in planning and presenting works such as written reports, pictures, videos, or models, as well as facilitating student collaboration.
5	Phase 5: Analyze and evaluate the problem-solving process	The teacher helps students to reflect on the results of the investigation and the steps used in the investigation. The teacher asks students to reconstruct their thoughts and activities during the learning that has been done.

(Sani, 2015)

C. Learning Theory

1. John Dewey

John Dewey explained the view of education where schools reflect society as a whole, and classrooms become real laboratories of discovery and problem solving (Arends, 2013). The teacher acts as a motivator for students to engage in problem solving projects and helps them investigate problems, guides and facilitates finding answers (Cherlin, 2020; Thomassen & Jørgensen, 2020).

2. Bruner's theory

Bruner's discovery learning is an important supporting theory of problem-based learning (Febrianti & Purwaningrum, 2021). Direct experience and observation of students themselves are expected to be able to obtain information and problem solving. Teachers are encouraged to be more of a facilitator than a presenter and demonstrator of information. A teaching model that emphasizes the importance of helping students. Teachers who use problem-based learning methods prioritize the active participation of students, are inductively oriented, find or build students' knowledge rather than giving students ideas or theories about the world (Arends, 2013). Learning starts from authentic problems, from real life and meaningful. Students have the opportunity to carry out investigations inside and outside the classroom to solve these problems so that students understand knowledge optimally, so in learning the teacher should provide optimal experiences for students, structure knowledge, present material appropriately and provide appropriate information. right (Zhou, 2020).

3. The Theory of David Ausubel

Ausubel's theory states that learning is meaningful for students who are able to solve their life problems. Meaningful learning theory is a series of learning processes that provide meaningful results. Learning can be said to be meaningful if the information learned by students is arranged according to their cognitive structure, so that students can associate new knowledge with their cognitive structure. Based on this theory, in helping students to instill new knowledge, it is necessary to have initial concepts that students already have that are related to the concepts to be studied (Lins et al., 2020; Silva, 2020).

4. Vygotsky's Theory

Vygotsky believed that Intelligence grows when people try to deal with it and work out the differences brought up by new experiences that confuse them. People associate new knowledge with previous knowledge and construct new meanings in search of understanding (Arends, 2013).

Vygotsky believed that social interaction that occurs between students and other people can improve the intellectual development of students and spur the formation of new ideas. Vygotsky's interest in the social aspects of students reveals the main idea, namely the concept of the zone of proximal development. Vygotsky revealed that students have two different stages of development: the actual stage and the potential development stage (Clarà, 2017; Jawad et al., 2021).

D. TPACK Integrated Learning

The tough challenge facing the world of education in this complex global era is the ability of teachers to design teacher competency development plans, especially aspects of Technological Pedagogical Content Knowledge (TPACK). According to Saubern et al. (2019), TPACK is a framework for understanding and describing the type of knowledge needed by a teacher to make effective pedagogical practices and understand concepts. by integrating technology into the learning environment.

TPACK according to Misra (2016), is a framework for understanding and describing the type of knowledge needed by a teacher, to streamline pedagogical practices and understand concepts by integrating a technology in the learning environment. The importance of TPACK according to several researchers is presented in Figure 2.1.

Figure 2. 1. Definition of TPACK

TPACK emerges from knowledge that goes beyond the three core components (Content, Pedagogy, and Technology), technology pedagogic content knowledge is understanding that emerges from the interaction between content knowledge, pedagogy, and technology (Mishra & Koehler, 2008). The TPACK framework resulted from the development of Mishra & Koehler as presented in Figure 2.2.

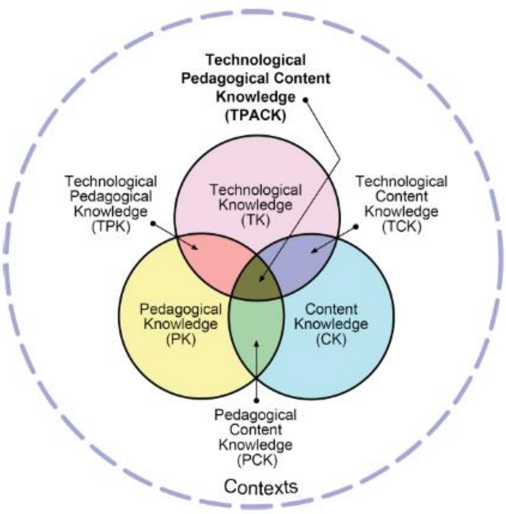


Figure 2. 2. Framework of TPACK
(source: http://tpack.org)

Professional teachers must have adequate TPACK competencies, because TPACK is included in the four main competencies of a teacher, namely pedagogical competence, personal competence, social competence, and professional competence. According to their research findings, Doering, Veletsianos, Schrber, and Miller (2009) found that integrating TPACK was able to increase teacher confidence as well as content, pedagogical, and technological competencies in designing lessons. Therefore, the TPACK pattern in building teacher competence is a good way to ensure that learning is carried out in accordance with current demands and changes. The following is a description of each TPACK component.

1. **Content Knowledge (CK)**

Knowledge of concepts, theories, ideas, conceptual organizational frameworks, empirical evidence, standard practices, and approaches in developing this knowledge constitutes CK, where the teacher's knowledge of the field of study that is being studied or that will be taught to students. (Schmid et al., 2021).

2. **Pedagogical Knowledge (PK)**

PK is a teaching process that includes methods such as managing classes, providing assessments, lesson planning, and student learning processes. The overall goal of knowledge in teaching is referred to as pedagogical knowledge (PK). Teachers must have teaching skills to manage and organize classes in learning activities and achieve predetermined goals (Haron et al., 2021; Kind & Chan, 2019).

3. **Technological knowledge (TK)**

Knowledge of various technologies, from the earliest to the newest, including digital technologies, is referred to as technological knowledge (TK). The application of technology must develop and adapt to the times. Understanding how to use software, hardware, or technology in an educational context is part of kindergarten. It is necessary to have the capacity to learn and adapt to technology because technological developments and changes will continue to develop (Gómez-Trigueros et al., 2019; Seufert et al., 2021).

4. **Pedagogical Content Knowledge (PCK)**

PCK is pedagogical knowledge applicable to specific content teaching. This knowledge includes understanding how content elements can be arranged for effective learning and appropriate teaching approaches (Mirshra & Koehler, 2006). According to Philips & Harris (2018), effective teaching requires more than separating pedagogy and content. PCK also recognizes that different teaching strategies will work best with different content. PCK is an acknowledgment that teachers do not just transfer concepts and skills from teachers to students, but are also complex and problematic on-the-spot decision-making activities (Kind & Chan, 2019).

5. ***Technological content knowledge* (TCK)**

Knowledge of how technology can change the perception of certain materials is TCK. Teachers can take a new approach using TCK for content or material to be taught to students. TCK describes knowledge of the interrelationships between technology and content. Technology will have an impact on what is known and the introduction of new things, so that it will affect how someone can describe content (material) in a different way than before. (Ozudogru & Ozudogru, 2019).

6. ***Technological pedagogical knowledge* (TPK)**

Knowledge of Pedagogical Technology (TPK) is an integration between pedagogical knowledge (PK) and technological knowledge (TK). TPK is knowledge of how technology can facilitate pedagogic approaches (Ammade et al., 2020; Andyani et al., 2020). Examples of TPK are the use of liveworksheet applications to facilitate problem-based learning in discussions of solving global warming problems, YouTube, Google Drive which contain worksheets to facilitate investigations of solving problems related to global warming.

7. **Technological Pedagogical and Content Knowledge (TPACK)**

TPACK is an integration between PCK, TPK, and TCK. TPACK is knowledge about the complex interaction of domain knowledge principles (content, pedagogy, technology). Learning in modern times requires teacher understanding to be able to collaborate with technology. Simply put, TPACK is teacher knowledge about when, where, and how to use technology while helping students expand their knowledge and skills in certain subject areas (Ammade et al., 2020; Arya et al., 2020).

E. The relationship between the PBL model and TPACK

Learning is a process of interaction between students and educators and learning resources in a learning environment. In carrying out learning, educators or teachers need to design learning by one of them applying a learning model that is appropriate to the material and learning objectives to be achieved. One of the learning models that can be used in presenting problems in everyday life is a problem-based learning model.

Besides being able to choose the right learning model, teachers must also be able to integrate technological, pedagogical, and content knowledge in the learning process which is known as TPACK-based learning. So, the teacher's challenge in designing lesson plans is being able to integrate various aspects such as higher order thinking skills and TPACK. Figure 2.3 shows the network visualization between learning, PBL, and TPACK.

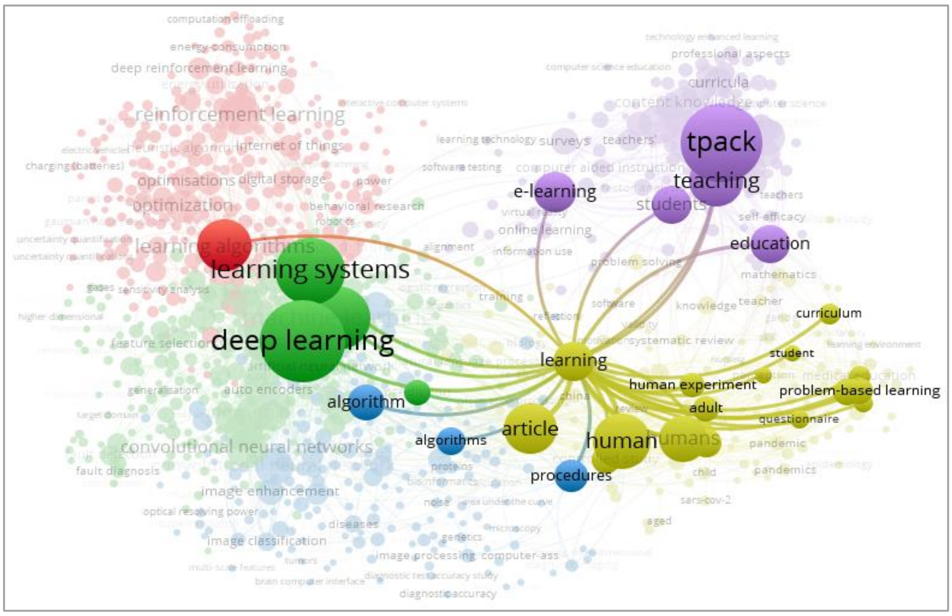


Figure 2. 3. *Network visualization in term of the learning*

It can be seen that in Figure 2.3 the term learning is related to problem-based learning and TPACK with 498 links, 1738 total link strengths, and 138 occurrences. This means that learning with the TPACK-integrated PBL model is indispensable for current learning to answer the challenges of 21st century learning. Professional teachers must have sufficient TPACK competence and in designing lesson plans must be able to integrate it with higher-order thinking skills. In addition, there are also many researchers and have the opportunity to conduct further research on TPACK-integrated PBL learning.

The ability of the teacher's TPACK can be seen from the preparation of the Learning Implementation Plan (RPP) because it contains pedagogic elements that can be seen from the methods used, content elements seen from the material and technological elements seen from the media used. Furthermore, it can be seen from the suitability of lesson plans with the implementation of learning carried out by the teacher in the classroom. This TPACK ability is very important for teachers, because in today's modern era it requires teachers' understanding to be able to collaborate learning with technology. Learning activities with the TPACK-integrated PBL model in general can be described through the diagram presented in Figure 2.4. Specifically, the integration of TPACK in learning with the problem-based learning model on global warming material is presented in the lesson plans contained in Appendix 2.2.

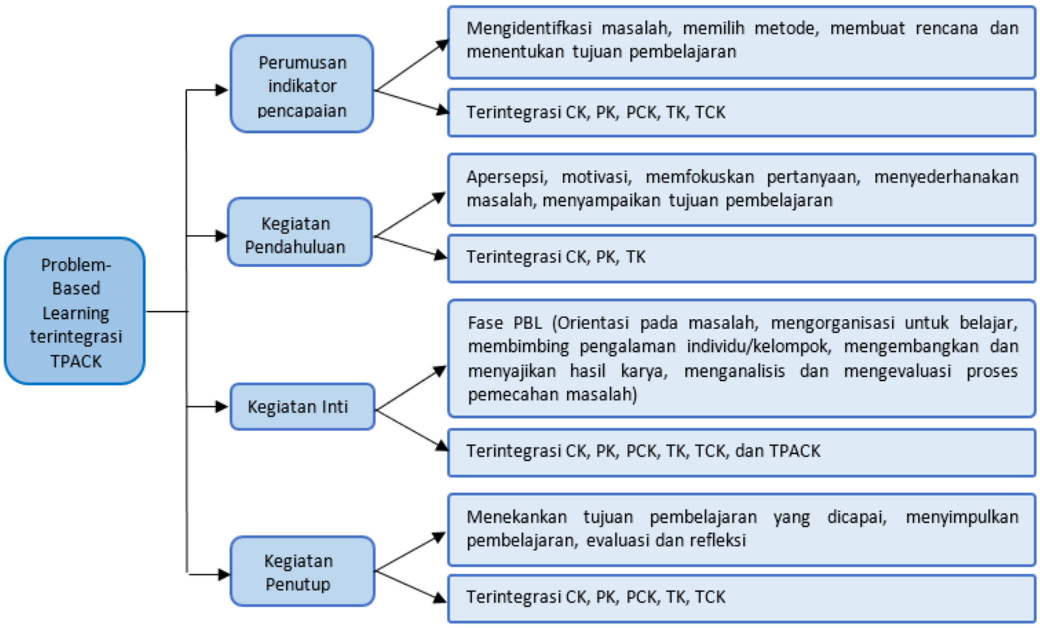


Figure 2. 4. The Relationship between PBL and TPACK in The Learning Plan

F. Science Literacy Skills (SLS)

1. Definition of Scientific Literacy

Literally, scientific literacy consists of the word literatus which means literacy and scientia which means knowledge. Scientific literacy according to PISA is defined as "the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (Budiarti & Tanta , 2021). The ability to identify questions, acquire new knowledge, explain scientific phenomena, draw conclusions based on facts, understand the characteristics of science, be aware of how science and technology affect the natural, intellectual and cultural environment, and be willing to participate in and care about scientific issues are all examples of literacy. science (MoEC, 2019; OECD, 2019).

Scientific literacy is very beneficial for individuals as well as the general public. Individuals who have scientific literacy skills have the ability to solve problems by using their scientific concepts (Rahmadani et al., 2018; Risa Bagasta et al., 2018). The involvement of students with ideas and issues related to science can be significantly improved by having scientific literacy skills. In addition, teachers in schools who have a strong understanding of a science can support and accommodate students' aspirations during the learning process. So, the essential thing about scientific literacy is being able to influence students in making decisions when facing social and personal problems. Meanwhile, the role of the educator is to influence the ability of students to view knowledge holistically (Jufrida, Basuki, Kurniawan, et al., 2019; Pahrudin et al., 2019).

This definition of scientific literacy shows that scientific literacy skills do not only require students to understand knowledge, but students must also be able to understand various aspects of the scientific process and the ability to apply their knowledge in real life. The demands of learning science, especially physics, are not only related to understanding concepts, principles, laws and theories, but also to increase the competence of students so that they are able to meet their needs and be able to keep abreast of educational developments in society which are Moderate being influenced by developments in science and technology (Mahmudah et al. , 2020; Rini et al., 2021).

2. Aspects of Scientific Literacy

The Organization for Economic Cooperation and Development (2018) in its PISA study, formulates scientific literacy competencies including explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence scientifically, as shown in Figure 2.5.

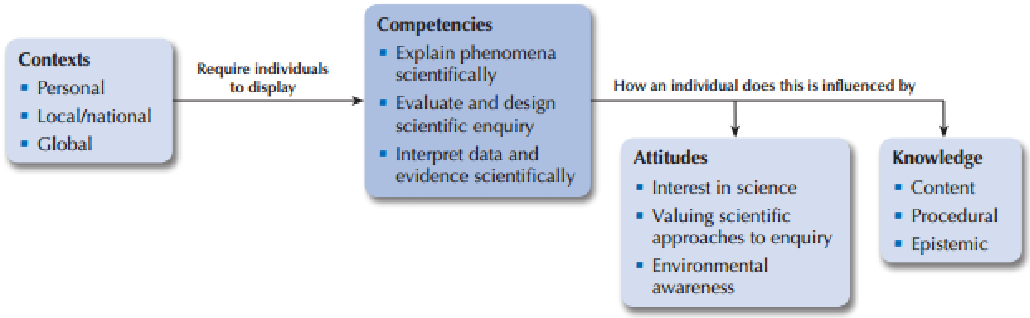


Figure 2. 5. Science Literacy Coverage

Based on Figure 2.5, in general, scientific literacy is divided into 4 dimensions, namely context, competencies, attitudes and knowledge. The four dimensions are interrelated where the context dimension requires individuals to bring up the dimensions of competencies, then the dimensions of competencies will have an impact on the dimensions of attitudes and knowledge. So that the dimensions of competencies will appear when the dimensions of context have appeared and the dimensions of attitudes and knowledge are influenced by the dimensions of competencies. Therefore the emergence of competencies dimensions can represent scientific literacy in students.

Content knowledge is knowledge that contains material (theories, concepts, and laws) in the fields of Physics, Biology, Chemistry, and Space and Earth Sciences. The material is selected that is relevant to everyday life. Knowledge related to scientific stages or procedures is referred to as procedural knowledge. It consists of: making observations, measuring with various tools, replicating investigations, processing and presenting data, and formulating findings or conclusions are all part of this process. Epistemic knowledge is knowledge related to the origin of how a knowledge is produced.

Content knowledge is equivalent to factual and conceptual knowledge, procedural knowledge does not differ in terms, and epistemic knowledge is comparable to metacognitive knowledge in Anderson and Krathwohl's revised taxonomy. If identifying and defining a particular variable is included in procedural knowledge, then the epistemic knowledge is to question why the identification and definition chosen for a variable like that? Epistemic knowledge includes explanations about the selection of certain tools, research designs, how many times data must be collected, and explanations of the kind.

3. Science Literacy Skills Indicator

There are three components of competency or scientific literacy skills, namely, 1) explaining scientific phenomena scientifically, 2) designing and evaluating scientific investigations, and 3) interpreting data and evidence scientifically on three types of knowledge. In addition, it is also distinguished at low, medium and high levels. Low level is the ability to mention simple facts or concepts. The ability to use conceptual knowledge to explain phenomena is at a moderate level. High levels include the ability to analyze complex information, synthesize evidence, perform evaluations, and design problem solutions. If a comparison is made with the revised Bloom's taxonomy, the low level is equivalent to C1; medium level equivalent to C2 and C3; and high levels equivalent to C4, C5, and C6. Indicators of scientific literacy skills can be packaged in Table 2.2.

Table 2. 2. Indicators of Science Literacy Skills

Indicator	Skills
Explain phenomena scientifically	Explaining phenomena scientifically includes remembering, identifying, recognizing, and explaining scientific and technological phenomena.
Evaluating and designing scientific investigations	The activities of evaluating and designing scientific investigations are asking scientific questions, proposing experimental designs, and evaluating scientific investigations.
Interpret data and evidence scientifically	Interpreting data and evidence scientifically includes analyzing and evaluating experimental data, opinions on various data, and drawing conclusions

(OECD, 2019)

Based on the description that has been explained, scientific literacy in this study is the capacity to 1) explain phenomena scientifically, 2) evaluate and design scientific investigations, and 3) interpret data and evidence scientifically. Students who are scientifically literate or scientifically literate are able to engage in issues related to science and technology that require competency. Scientific literacy is the foundation and indicator in dealing with issues that arise in problems in everyday life. Therefore, scientific literacy is applied to learning Physics on global warming which is expected to have a positive impact on increasing scientific literacy. The scientific literacy assessment is adjusted to several measurable indicators of ability or scientific literacy skills. Some of these indicators are used as a basis for measuring students' scientific literacy skills.

G. Forms of Science Literacy Problems

In an effort to improve the quality of education, especially multi-learning, the Ministry of Education and Culture (Kemendikbud) is making efforts to develop an assessment system, known as AKM (Minimum Competency Assessment). The purpose of AKM is to measure student achievement from cognitive learning outcomes, namely literacy and numeracy. This level of competence can be used by teachers to develop effective and quality learning strategies. AKM is a national assessment that supports Teaching at the right point, to produce accurate information to improve the quality of teaching and learning which has an impact on improving the quality of learning and student learning outcomes (Directorate of Elementary Schools, 2020).

In addition, the Ministry of Religion (Kemenag) was also triggered by implementing an assessment in the scope of Madrasah Education called AKMI (Assessment of Indonesian Madrasa Competency). AKMI in the realm of knowledge elaborates socio-cultural literacy and literacy to support reading and mathematical literacy. The form of questions from AKMI consists of multiple choice, complex multiple choice, true/false, matching and short entries. Whereas in AKM the form of questions consisted of multiple choice, complex multiple choice, matchmaking, short entries, and descriptions. Even though AKM and AKMI have different characteristics and assessments, both of them have the same goal, namely measuring students' literacy abilities and character surveys (Safari, 2021; Wijaya & Dewayani, 2021).

Based on the description above, the researcher was inspired to make a scientific literacy test with various forms of questions on global warming material. Researchers use an online platform, namely Live Worksheets to create a scientific literacy test. Live Worksheets was chosen as the evaluation media because this software can be accessed for free and easy to use. In addition, Live Worksheets can facilitate the teacher's work in providing or correcting student answers for multiple choice, true/false, matchmaking, and short entries, and can correct answers automatically. Students can immediately find out the value of the learning evaluation results or scientific literacy tests after finishing working on the questions. Forms of questions and descriptions of the forms of questions made by researchers are presented in Table 2.3.

Table 2. 3. Forms of Scientific Literacy Problem

No.	Problem Form	Live Worksheets feature	Description of the Question Form
1	Multiple Choice (MC)	Drop Down Select Box	Choose one correct answer from 4 statements
2	Complex Multiple Choice (CMC)	Multiple Choice Exercise	Choose two correct answers out of five statements
3	True/False (TF)	Multiple Choice Exercise	Choose an answer in the form of true or false which consists of 4 statements
4	Short Entries (SE)	Short Entry	Answer/short entry in the form of a name/word/term (one word without spaces or other characters)
5	Matchmaking (M)	Drag and Drop Join with Arrows	Link the corresponding right and left lane statements

H. Developed Science Literacy Indicators

Table 2.4 is an indicator of scientific literacy and an indicator of questions in learning developed by researchers.

Table 2. 4. Indicators of Science Literacy Questions and Question Indicators

No	Science Literacy Indicator	Sub-Indicators	Indicator Question
1	Explain phenomena scientifically	Recall and apply prior knowledge correctly	Identify statements related to the impact of global warming
		Identify problems	Identify problems related to the mechanism of the greenhouse effect
		Make predictions or hypotheses and explain correctly	Predict and explain solar radiation and the greenhouse effect
2	Evaluating and designing scientific investigations	Ask scientific questions in an experiment	Asking scientific questions (problem formulation) related to the Greenhouse Effect experiment
		Propose trial design	Proposing experimental variables through the Greenhouse Effect experiment
		Evaluate how experts ensure data is objective, real, and generalizable	Identify and evaluate related types of greenhouse gases and their residence in the atmosphere
3	Interpret data and evidence scientifically	Evaluate scientific opinions and facts from various literature such as the internet, journals, and books	Analyze statements regarding global warming and Eco-Friendly House
		Analyze data and draw conclusions	Identify and analyze the cycle of carbon dioxide (CO2)
		Distinguish between scientific opinion and unscientific opinion	Evaluate facts related to global warming and the greenhouse effect from an article
		Identify concepts, facts, theories related to science	Interpret, analyze, and conclude data related to CO2 levels, temperature rise, and the amount of ice mass in the world.

I. Problem Solving Skills

Problem solving skills are one of the skills that must be possessed by students in accordance with the demands of the 21st century. Problem solving skills. According to KBBI problem solving is defined as a process to find a solution to a difficult or complex problem. The ability to solve a problem, especially solving complex problems in the form of real problems in people's lives, is one of the skills that must be possessed by the human resources of a country (Hidaayatullah et al., 2020). If the problem-solving skills possessed by the community are low, it will result in the low quality of the country's human resources. Several studies have shown that many students do not have problem solving skills. This is due to a lack of knowledge or strategies that are owned so that problem solving appears that does not only include cognitive aspects but also motivational and emotional aspects (Hasan et al., 2021; Setyarini et al., 2021).

Polya (1973) menyebutkan bahwa pemecahan masalah merupakan sebuah usaha mencari jalan keluar dari suatu kesulitan. Terdapat empat tahap pemecahan masalah yaitu; (1) memahami masalah, (2) merencanakan pemecahan, (3) melaksanakan rencana, (4) memeriksa kembali. Diagram pemecahan masalah Polya dapat dilihat pada Gambar 2.6.

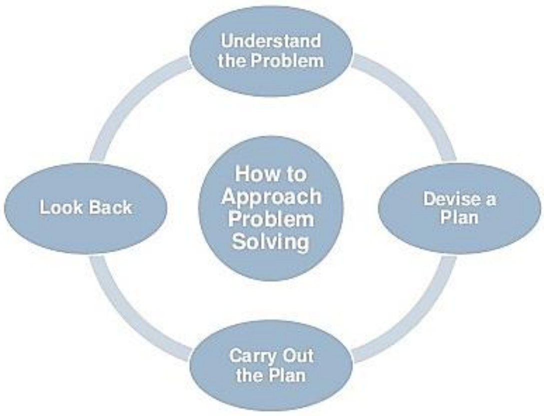


Figure 2.6. Problem Solving Stages Diagram
(source: www.kajianpustaka.com)

From the diagram of the stages of solving the problem above, it can be broken down as follows (Polya, 1973):

1) Understand the Problem

The first stage in problem solving is understanding the problem. Participants must identify what is known, what exists, the amount, the relationships and values associated with it and what they are looking for. Some suggestions to help students understand complex problems: i) ask about what is known and sought, ii) describe the problem in their own words, iii) relate it to other similar problems, iv) focus on important aspects of the problem, v) create models, and vi) draw diagrams.

2) Devise a Plan

Learners need to identify the operations involved as well as the strategies needed to solve a given problem. Students can do this in several ways, such as: i) guess, ii) make models, iii) draw diagrams, iv) simplify problems, v) find patterns, v) make tables, vii) experiment and simulation, viii) work in reverse , ix) testing all possibilities, x) finding sub-objectives, xi) making analogies, and xi) sorting data and information.

3) Carry Out The Plan

Naturally, what is done depends on what is planned beforehand, and this includes the following: i) interpreting the information given mathematically; and (ii) realizing the plan while the process and calculations are in progress. As a general rule, at this stage students must follow the plan that has been chosen. Learners must have the option to choose a different strategy or method if the plan cannot be implemented.

4) Looking Back

When reviewing the steps previously taken to resolve the problem, the following factors should be considered: i) Verify again all important information that has been identified; ii) Verification of any calculations involved; iii) Evaluate the logic of the solution; (iv) investigate other potential solutions; and (v) read the question again and consider whether it has been answered or not.

According to Gopinath & Lertlit (2017) solving Polya problems can make it easier for students to solve problems and the steps given in solving problems are more efficient. In solving the problem, several steps are needed to get a solution. The problem solving process carried out to improve problem solving skills uses science process skills. The following science process skills that have been developed by Nur (2011) are as follows:

1) Formulate problems

When formulating a problem, the problem to be formulated must be operational in nature so that it can assist students in formulating hypotheses that can be answered based on evidence or based on the results of investigations. Instructions for training students in formulating problems such as (a) starting to make scientific questions; (b) Resolving universal questions into specific questions so that they can be investigated; (c) Formulate questions that can be answered.

2) Formulate Hypotheses

The hypothesis is formulated based on prior knowledge. Hypotheses can be tested in the form of investigations so as to obtain evidence to show whether the hypothesis that has been made is right or wrong. Instructions that can be used to train skills in formulating hypotheses are (a) Hypotheses are formulated based on the problems or questions that have been asked; (b) The hypothesis formulated must be testable; (c) The hypothesis is formulated not in the form of a question but in the form of an "if...then..." statement.

3) Plan an experiment

Planning an experiment is one that can be used to test a hypothesis. In planning an experiment, it can be done by identifying variables, identifying variables operationally, planning the experimental steps and planning the data table results from the experiment.

4) Conduct experiments or observations

An experiment is an activity carried out to answer a problem or test a hypothesis. So that students must be objective, systematic, logical, and thorough in conducting experiments.

5) Analyze data

In analyzing the data it is necessary to explain the data to obtain experimental results. In analyzing the data can be done by comparing or searching for the data that has been analyzed.

6) Make conclusions

Concluding is making statements that have been learned based on experiments or observations that have been carried out. Conclusions in an experiment are closely related to the formulation of the hypothesis that has been made before.

J. Problem Solving Indicators Developed

Skills solving problem is ability somebody For find solution through an involved process acquisition and organization information . Polya state that there is four stages moment do ability solving problem that is *understanding the problem* or understand problem , *devising a plan* or compile plan completion , *carrying out the plan* or carry out plan resolution , and *looking back* or inspect back . Based on Steps solving problem from Polya , which already discussed before , then Table 2.5 researchers serve details indicator solving problems and indicators questions developed on the material global warming.

Table 2. 5. Problem Solving Indicator and Question Indicator

No	Indicator Solving Problem	Sub- Indicators	Indicator Question
1	Understand problem	identify or formulate problem	identify problem related activity man who can increase GHG emissions
			identify problem related reason global warming and efforts minimize impact
			identify problem related impact from burning rubbish
			Identify and formulate problem related The role of gases presented in the experimental table *molecules and light*
2	Plan settlement	Meru muskan alternative solution strategy problem	Formulate alternative solution strategy related activity man who can increase GHG emissions
			Formulate alternative solution strategy related reason global warming and efforts minimize impact
			Formulate alternative solution strategy related impact from burning rubbish
			Formulate alternative solution strategy related The role of gases presented in the experimental table *molecules and light*
3	Carry out plan	Take right decision / solution _ For overcome problem	Give decision / solution related problem activity man who can increase GHG emissions
			Give decision / solution related problem reason global warming and efforts minimize impact

No	Indicator Solving Problem	Sub- Indicators	Indicator Question
			Give decision / solution related problem impact from burning rubbish
			Give decision / solution related problem The role of gases presented in the experimental table *molecules and light*
4	Review process and results	Evaluate or check return process and results solving problem	Evaluate return process and results solving problem related problem activity man who can increase GHG emissions
			Evaluate return process and results solving problem related problem reason global warming and efforts minimize impact
			Evaluate return process and results solving problem related problem impact from burning rubbish
			Evaluate return process and results solving problem related problem The role of gases presented in the experimental table *molecules and light*

K. The Linkage of TPACK Integrated PBL to Science Literacy and Problem-Solving Skills

As for linkage between integrated *problem-based learning* models *Technological Pedagogical Content Knowledge* (TPACK) with Skills literacy science (KLS) and skills solving problems (KPM) are presented in Table 2.6.

Table 2. 6. The Linkage between PBL-TPACK and Science Literacy and Problem Solving Skills

PBL phase	Indicator Skills Science Literacy (KLS)	Indicator Skills Solving Problem (KPM)	TPACK Integrated Teacher Activities
Problem orientation	Explain phenomenon in a manner scientific	Understand problem	Convey objective learning and motivating participant educate . Serve various problem and participants educate capable identify problem (CK , PK, Kindergarten)

PBL phase	Indicator Skills Science Literacy (KLS)	Indicator Skills Solving Problem (KPM)	TPACK Integrated Teacher Activities
Organize For Study	Explain phenomenon in a manner scientific	Make plan settlement	Help participant educate define , organize related tasks _ with problem , and determine type required information _ For reach solutions (CK, TK, TCK, TPACK)
Guide individual/ group experience	Evaluate & design investigation scientific	Carry out plan	Guide participant educate For gather right information . _ Furthermore do experiment , and search explanation as well as settlement problems (PCK, TCK, TPACK)
Develop and present results work	Interpret / interpret data & evidence scientific	Carry out plan	Help participant educate in plan and prepare results work written like reports , videos, and models as well help participant educate share One related to each other results his work (CK, TPK, PCK, TPACK).
Analyze and evaluate the solving process problem	Interpret / interpret data & evidence scientific	Check and evaluate	Help participant educate For do reflection to results investigation and the processes used in investigation . Teacher asks participant educate For reconstruct thoughts and activities during past learning _ implemented (CK, PCK, TCK)

L. Global Warming Matter

1. Definisi Pemanasan Global

Global warming is incident increasing surface average temperature Earth . Based on United State Environmental Protection Agency (US EPA), global warming can also defined as enhancement surface average temperature earth consequence exists house gas emissions glass (GHG). This global warming become moderately important and critical issues _ _ faced by the world today this (Freije et al., 2017). Experts _ climatology estimate that temperature atmosphere Earth increase by 0.5° C since 100 years ago , even based on observation for 30 years final increase the average temperature around the world reaches 1°C.

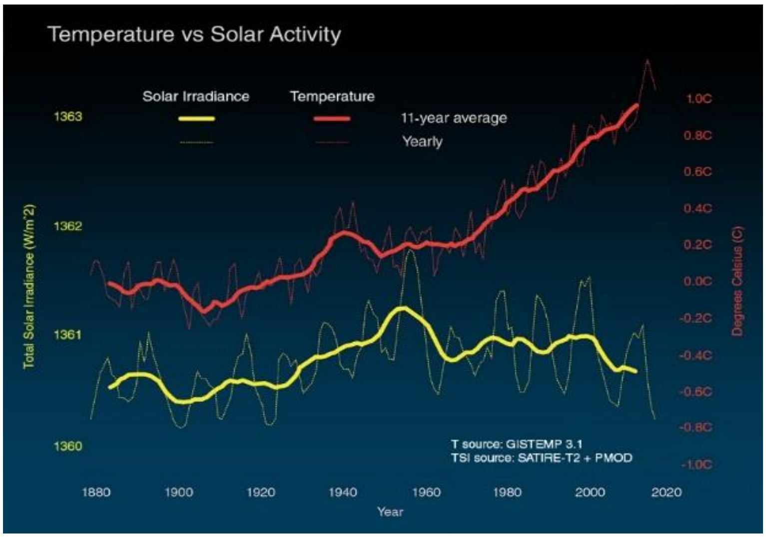


Figure 2.7. Comparison of Earth's temperature and solar radiation energy (sumber: climate.nasa.gov)

United States Space Agency (NASA) regarding comparison radiation and temperature earth say that : Total radiation received sun _ earth is a constant relative , follows cycle natural (without exists significant increase) since _ 1950s (shown in graph . Yellow is heat by radiation sun & red global temperature). However during period the same time , temperature earth has increases (red line). because _ it's so not Possible that Sun is reason enhancement trend global heat . *The Intergovernmental Panel on Climate Change* (IPCC) concluded that part big enhancement global average temperature since _ mid 20th century possibility big caused by increases gas concentration _ House glass consequence activity human " through effect House glass " (Rueangphankun et al., 2018) .

2. Effect House Glass

Ray sun can until to surface earth after pass atmosphere earth . Atmosphere earth is surrounding gas layer earth , from surface until way outside _ space .

Reported from the Encyclopedia Britannica, that atmosphere is gas layer with thickness thousands of kilometers consisting from a number of layer. Layer atmosphere consists from a number of layer that is troposphere, stratosphere , mesosphere , thermosphere , and exosphere (Figure 2.7). on each layer atmosphere have different temperatures and functions. Gas composition inside atmosphere that is consists of oxygen gas (O_2), carbon gas dioxide (CO_2), Nitrogen (N_2), Neon (Ne), argon (Ar), xenon (Xe), krypton (Kr), helium (He), hydrogen gas (H_2), and ozone (O_3) (Sproul et al., 2019; Tuckett, 2019) .

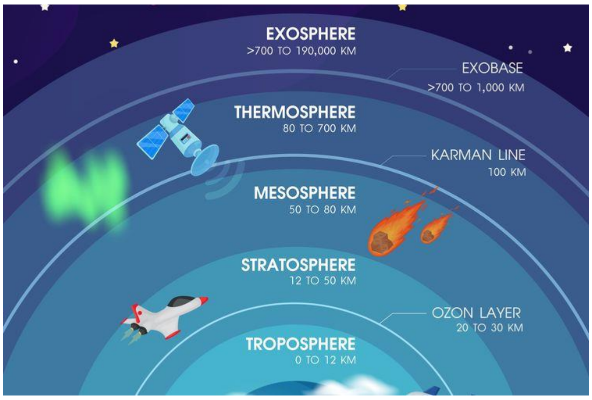


Figure 2.7. Illustration of Atmosphere Layers
(source: www.geologinesia.com)

Source energy on earth originate from sun , radiation ray sun that is consists from wave short and wavy long . Wave short consists from ultraviolet (UV) rays while Long wave ie ray infrared. Atmosphere function manage the admissions process hot from ray sun. Atmosphere do absorption , scattering , and reflection emitted heat _ sun (Plane, 2012; Zahnle et al., 2010) . In Figure 2.8 is illustration distribution radiation incoming sun _ to surface earth. Seen that radiation sun in his journey pass atmosphere going to surface earth that is experience reflection, absorption , and scattering . Surface earth, only absorb part hot from radiation sun . Part of hot emitted return to atmosphere in form radiation infrared or long waves (Figure 2.9).

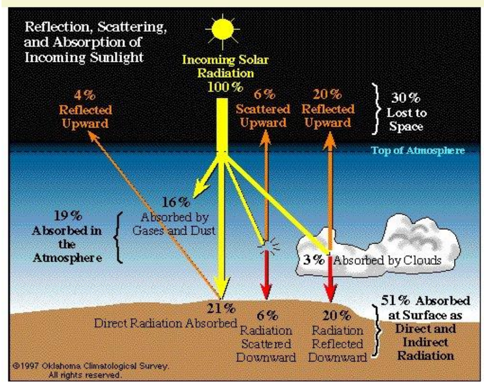


Figure 2. 8. Distribution of Solar Radiation
(source: www.researchgate.net)

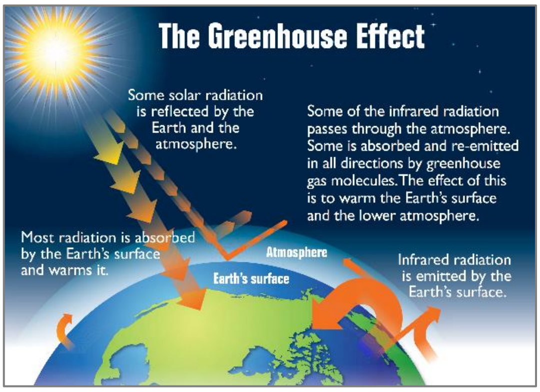


Figure 2. 9. Illustration of the Greenhouse Effect
(source: www.earthjournalism.net)

However, some are hot radiation sun still trapped in the atmosphere earth consequence presence of house gases glass including carbon gas dioxide (CO_2), water vapor (H_2O), methane (CH_4), nitrogen oxides (N_2O), and green-house gases glass others to be trap wave radiation the . House gases kada function absorb, scatter, and reflect return radiation emitted waves _ earth . So that resulted hot the will stored on the surface earth . circumstances like This happen in a manner Keep going continuously so that resulted annual average temperature earth Keep going increase. Figure 2.10 shows the gases in the atmosphere and the gases that play a role as House glass (*greenhouse gases*).

Atmospheric Gases	Chemical Symbol	Percent by Volume in the Atmosphere	Concentration in Parts Per Million (ppm)*	Average Residence time**	Variability over time and spatial scales
Non-greenhouse Gases					
Nitrogen	N_2	78.1%	780,840 ppm	1.6×10^7 years	Constant
Oxygen	O_2	20.9%	209,460 ppm	3×10^3- 10^4 years	Constant
Argon	Ar	0.9%	9,340 ppm	NA	Constant
Greenhouse Gases					
Carbon Dioxide	CO_2	0.0397%	397 ppm	100 -300 years	Variable
Methane	CH_4	0.000179%	1.79 ppm	10-12 years	Variable
Nitrous oxide	N_20	0.0000325%	0.3 ppm	121 years 150	Variable
Ozone	O_3	0.00004%	0.01 -0.5 ppm	hours-days	Highly variable
Water Vapor	H_20	Variable 0.001% to 0.5% Strongly varies locally	10-50,000 ppm	8-10 days	Highly variable
Chlorofluorocarbons (CFCs)	Contain C and H	0.0000002	0.0002 ppm	9 yrs to 3200 yrs depending on type of CFC molecule	Highly variable

Data Sources: CDIAC, IPCC

Figure 2.10. Composition in the Atmosphere
(source: https://www.epa.gov)

Effect House glass (*greenhouse effect*) is needed by all creature life that is on earth , without exists effect House glass earth will it feels so cold . Without presence of house gases glass and effects processes House glass , temperature earth only -18 ºC so the ice will be cover whole surface earth (Boesch et al., 2021; Kweku et al., 2018; Mikhaylov et al., 2020) . However _ conversely , if the gases concentration excess in the atmosphere , then will resulted global warming or *global warming* (IPCC, 2018) . Global warming is happening moment temperature on earth is rising marked significance _ with things among others like melting of polar ice caps , destruction ecosystem , rising height sea level and changes _ extreme climate _ (El-Sayed & Kamel, 2020) .

Figure 2.11 represents comparison earth then and now in accept radiation ray sun . Condition experience should be the house gases glass absorb and reflect return radiation emitted waves _ earth so that earth become warm . However , conditions _ moment This that is house gas concentrations glass in the atmosphere increase so that the more Lots the heat that rises underneath . House gas imbalance glass in the atmosphere moment This can dating continuity life various creature occupants earth . *The National Oceanic and Atmospheric Administration* (NOAA) reports that house gas concentration glass in the atmosphere reach 414.7 ppm by 2021 , figures That's 2.3 ppm more High than year previously (NOAA, 2022) .

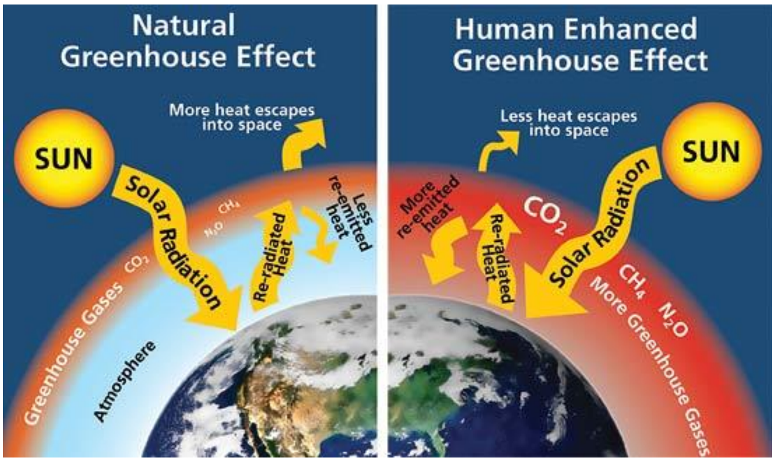
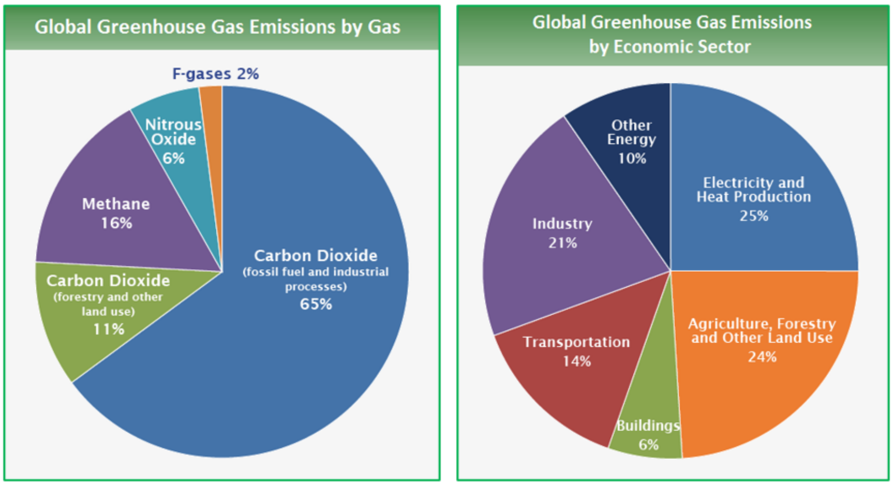


Figure 2.11. The Current Greenhouse Effect
(source: www.science.org.au)

Problem happened _ moment This is activity human , like burning material burn fossils (coal , oil and natural gas), agriculture , surface land and other industrial activities contribute speed up enhancement house gas concentration glass (Figure 2.12). this _ show exists effect House improved glass , which causes happening global warming . In A book entitled _ *Climate Science Special Report* written by the team from the National Science Foundation and US Global Change Research Program mentions that activity man is pusher main increase recent global temperatures This compared to natural processes in a manner experience (Wuebbles, 2021) . Percentage activity human and industrial activities that contribute contributing to house gas glass presented in Figure 2.13 (IPCC, 2018) .

Figure 2.12. Illustration of Human Activities Contributing to Greenhouse Gases (source: https://climatevisuals.org/)



Gambar 2.13. Global Greenhouse Gas Emissions (source: www.epa.gov)

3. Reason Global Warming

All form activity man always impact for environment , fine That bring impact positive or impact negative . Likewise with condition atmosphere Earth moment experienced this change consequence activity human . Burning material burn fossils and logging forest can increase CO_2 gas levels in the atmosphere. Reaction chemistry from the combustion process the can written down as following.

$$2C_8H_{18} + 25O_2 \rightarrow 8CO + 8CO_2 + 18H_2O$$

Due to CO_2 gas is a house gas glass, then increasing CO_2 gas levels in the atmosphere will contribute happening global warming . because that, every year CO_2 gas levels in the atmosphere Keep going continuously increase. Following explanation more details regarding causes direct nor No resulting directly global warming:

a. Increase in house gases glass in the atmosphere that causes happening effect House glass globally . Every reason increase effect House glass also contributes direct to global warming such as :

1) Energy , almost part big generator electricity in the world that is use material burn fossil such as coal and oil earth . So will very big effect to global warming , due to demand electricity really high and on increase .

2) Transport , almost the entire transportation system use material burn fossil . So , more and more many use _ vehicle personal will impact on the increase of CO_2 gas in the atmosphere .

3) Activity industry like livestock , agriculture , factories , and waste House Stairs also contribute contributing to house gas glass . Due to activities the produce exhaust gas or possible emissions _ increasing house gases glass . Methane gas (CH_4) is produced from the livestock industry , activities agriculture that is *nitrous oxide* (N_2O), waste factory produce carbon gas emissions dioxide (CO_2).

b. Pollution sea , Pollution sea , ocean can absorb carbon dioxide in very large amount . However , result _ from pollution sea by waste industry and trash so sea become polluted so that Lots the ecosystem in it is destroyed , which causes sea No can absorb carbon dioxide again .

c. Burning forest and logging forest (*deforestation*). Burning and logging forests are very impactful bad Because forest can absorb carbon dioxide in the atmosphere .

4. Impact Global Warming

As stated _ before , that activity man has change house gas composition glass in the atmosphere . Difficult For predict effect house gas changes glass in the atmosphere , but a number of impact that has visible , that is as following (IPCC, 2018; Widodo et al., 2017; Zandalinas et al., 2021) :

a. Temperature earth the more high , in some area the temperature Possible more high and in other areas maybe no . Height temperature Earth can cause more Lots evaporation and bulk Rain in a manner overall , but each region will varies , some become wet and part other drought .
b. Surface the sea rises because glacier melt . Similar with plains sloping beach , will _ seen enhancement puddles from _ time to time .
c. loss reef coral . According to A report about reef coral , acidification sea and rise temperature , in case worst , will be cause extinction population coral in 2100. Because a lot other reef - dependent species coral For endure live .
d. Extinction species in a manner broad . More from One million species Can extinct consequence increase temperature , according research published in magazines _ *nature* . Until moment this , has happen lost species in a manner area and number threatened species _ extinct Keep going increase .
e. Failure harvest massive . Study latest show that in One century , there is a 90% chance that 3 billion people around the world have to choose between traveling with family they to friendly location _ climate or starving Because change climate .
f. Depletion layer ozone . one _ layer atmosphere that is in the stratosphere , about 17-25 kilometers above surface earth , is layer ozone . Earth protected from the dangers posed by ultraviolet (UV) radiation by the coating this .

g. Efforts to Tackle Global Warming

Whole humans in various parts of the world can take step real For combat global warming . Nature has _ exploited during This must controlled with ok . Refers to global warming above which is not reasonable , following a number of effort simple For get over it (IPCC, 2018; Widodo et al., 2017) :

a. Reduce use vehicle motorized
b. Control usage electricity
c. Guard sustainability natural
d. Control waste
e. Reduce activity logging and deforestation forest

f. Do reforestation
g. Use energy renewable and reduced use material material burn fossil
h. Support and participate as well as in activity greenery, etc.

M. Relevance Research

For support study this is presented findings results study previously relevant. As for some strengthening research _ study This is as following :

1) Chaidam & Poonputta (2022) in his research entitled " Learning Achievement Improvement of 1st Grade Students by Using Problem-Based Learning *(PBL) on TPACK Model* " states that results Study mathematics after using learning models based problem with the TPACK model significant more High compared to before using the Learning model based problem . Satisfaction participant educate in a manner whole to learning based problems in the TPACK model are at levels high .
2) Siregar et al. (2022) in his research entitled " *Table Tennis classes at Junior High Schools utilizing the TPACK-Based Problem-Based Learning* Model " stated that learning model problem TPACK- based renders learning more meaning and results Study participant junior high school students experience completeness classic .
3) Wardani & Jatmiko (2021) in his research entitled " *The Effectiveness of Tpack -Based Learning Physics with The PBL Model to Improve Students' Critical Thinking* Skills " states that learning physics TPACK- based with the PBL model can made as material input for teachers to increase ability think critical participant educate .
4) Stefani et al. (2021) in his research entitled " Improving the Learning Process thematic Integrated with Using the TPACK- Based Problem Based Learning (PBL) Model in Class V SDN 07 Pandam Gadang " obtain results study that Based Problem Based Learning (PBL) model Thecnological , Pedagogical And Content Knowledge (TPACK) can improve the learning process thematic integrated in class school basic .
5) Kamid et al. (2021) in his research entitled " Impact of the Integration of Ethno-mathematics with TPACK framework as a problem- based *learning (PBL)*

model " obtained results that learning ethnomathematics with PBL model-assisted TPACK intervention can more effective compared to with learning models ethnomathematics simple .

6) Abasari et al. (2020) in his research entitled " *The Effectiveness of Technology, Pedagogy and Content Knowledge (TPACK) in* Learning " obtained results study that PK had an effect positive against TPACK, while TK and CK did not influential positive against TPACK. Furthermore TK, TPK, PK have an effect positive on TPK, and TPK has an effect positive against TPACK. Study this also suggests that age influence development knowledge technology .
7) Ilmi et al. (2020) in his research entitled " Development of TPACK based-physics learning *media to improve HOTS and scientific attitude* " shows that learning TPACK based is effective learning _ For in activity learning physics and the development of learning media can increase HOTS and attitudes scientific .
8) Oktasari et al. (2020) in his research entitled " *Instructional Technology: Teacher's Initial Perception of TPACK in Physics* Learning " states that demands learning in the current industrial era 4.0 This impact on innovative learning , design _ learning with framework *Technology Pedagogic and Content Knowledge* (TPACK) provides useful framework _ for teachers to integrate technology in activity learning .
9) Gustia et al. (Gustia et al., 2019) in his research entitled " *Effect of Model Problem Solving on Student's Problem Solving Skills In Climate Change Material Class* VII SMPN 34 Padang" states that the application of the problem solving model has an effect positive to Skills solving problem participant educate class VII SMPN 34 Padang, where activity Skills solving problem participant teach in class experiment more High compared to with class control .

N. Thinking Framework

REALITY

1. Low application of TPACK in learning
2. Learning is done only limited to lectures and memorization
3. Have never trained students' scientific literacy and problem-solving skills
4. There is no physics learning tool that trains scientific literacy and problem-solving skills.

HOPE

1. TPACK as an approach to learning in order to produce an effective, efficient and more interesting learning process.
2. Learning with the PBL model is expected to be able to train students' scientific literacy and problem-solving skills
3. Availability of physics learning tools that can train students' scientific literacy and problem-solving skills.

PROBLEM

How is the feasibility of the TPACK-integrated Problem Based Learning (PBL) Physics learning device to improve students' scientific literacy skills and problem solving in the material global warming?

SUPPORTING THEORY

1. John Dewey
   Education in schools will reflect the wider society and the classroom will become a laboratory for real inquiry and problem solving.
2. Bruner and discovery learning
   Learners are expected to use direct experience and their own observations to obtain information and solve problems.
3. David Ausubel's meaningful learning theory
   Ausubel's theory states that learning is meaningful for students who are able to solve life problems.
4. Vygotsky's theory of Social Cognition
   Vygotsky believed that social interaction that occurs between students and other people can spur the formation of new ideas and enhance students' intellectual development.
5. Problem-Based Learning (PBL) is a learning model that presents various problems in the real world of students to serve as learning resources and tools (Sani & Hayati, 2018) (Arie et al., 2020).
6. Technological Pedagogic Content Knowledge is an optimization of technology used in learning to produce an effective, efficient and more interesting learning process (Rahman, 2015).

RELEVANT RESEARCH

1. Chaidam & Poonputta (2022) with the title "Learning Achievement Improvement of 1st Grade Students by Using Problem-Based Learning (PBL) on TPACK Model" states that learning outcomes after using the problem-based learning model in the TPACK model are significantly higher than learning conventional.
2. Siregar et al. (2022) with the title "Table Tennis classes at Junior High Schools utilizing the TPACK-Based Problem-Based Learning Model" states that the TPACK-based problem learning model makes learning more meaningful and the learning outcomes of junior high school students experience classical mastery.
3. Wardani & Jatmiko (2021) with the title "The Effectiveness of Tpack-Based Learning Physics with The PBL Model to Improve Students' Critical Thinking Skills" states that TPACK-based physics learning with the PBL model can improve students' critical thinking skills.
4. Ilmi et al. (2020) with the title "Development of TPACK based-physics learning media to improve HOTS and scientific attitude" shows that TPACK-based learning is effective learning for physics learning activities.

SOLUTION

Availability of TPACK-integrated Problem Based Learning (PBL) Physics learning tools to improve students' scientific literacy and problem solving skills on global warming material

EXPECTED RESULTS

Availability of physics learning tools that are suitable for use in learning to improve scientific literacy and problem solving skills of students on global warming material

CHAPTER III
RESEARCH METHOD

A. Type of Research

The 4D development model (Define, Design, Develop, and Disseminate) is used in this development study. The development carried out is to develop learning tools for the Problem Based Learning (PBL) model integrated with Technological Pedagogical Content Knowledge (TPACK) developed to improve scientific literacy and problem solving skills of Lamongan 2 MAN students related to global warming material.

B. Research Subjects

The subjects in this study were the TPACK-integrated PBL tools which included: (1) syllabus; (2) Handou; (3) Learning Implementation Plan (RPP); (4) Student Worksheets (LKPD); and (5) Evaluation Sheet (LE). The learning device trial phase was implemented in class X students on global warming material.

C. Place and Time of Research

The implementation phase of this research was carried out in the 2022/23 academic year at MAN 2 Lamongan, while research on the development of learning tools was carried out at the Postgraduate Program at the State University of Surabaya (UNESA).

D. Research Design

The development of learning tools aims to obtain a learning device that is suitable for use. The eligibility includes: 1) the device has gone through the validation stage by an expert as a validator; 2) the practicality of the device has been tested, and 3) the device has been tested for its effectiveness in learning. The development model used is the 4-D model (four D models) which consists of the define, design, develop and disseminate stages. The 4D model is shown in Figure 3.1.

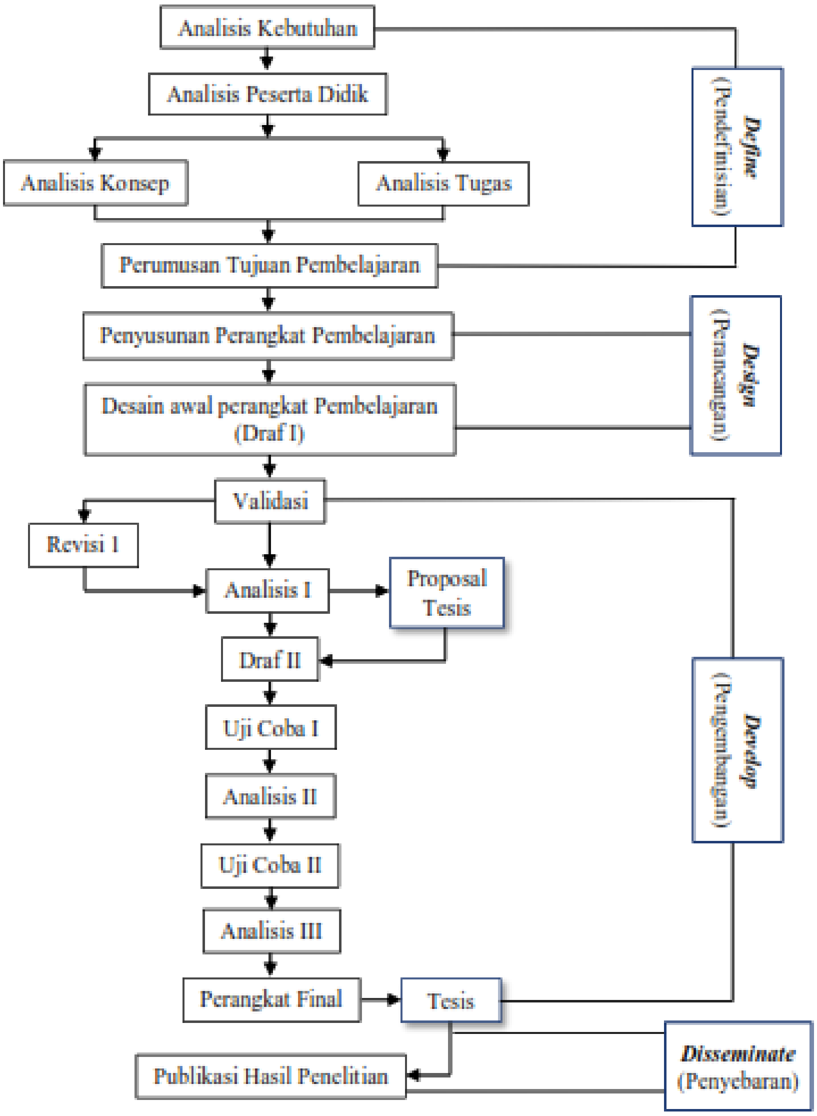


Figure 3.1. Learning Tool Development Flowchart

Based on the research learning design in Figure 3.1 The flow of developing the TPACK-integrated PBL model learning tools to increase scientific literacy and problem-solving skills in this study is described as follows:

1) **Stage I: Define (Define)**

Define(Defining) is the first stage in the development of learning tools that have the goal of defining learning requirements. Curriculum analysis, student analysis, task analysis, concept analysis, and the formulation of learning objectives are part of the defining stage.

a. Needs Analysis

Needs analysis aims to identify and apply the basic issues that will be raised in the development of learning tools. The curriculum used in the development of this device is the 2013 curriculum. In carrying out learning, MAN 2 Lamongan uses the revised 2013 curriculum and uses textbooks that have been provided by the government in learning. Global warming material is only presented at a glance and has never carried out experimental activities to understand more deeply about the material, as well as students' scientific literacy and problem solving skills are still weak or need to be improved. Based on the front end analysis performed,

Based on the core competencies and basic competencies that have been made by the central government for equality as well as to avoid differences in each delivery of material, the researchers describe the competency achievement indicators as follows:

Table 3.1. Basic Competencies and Competency Achievement Indicators

Basic competencies		**Indicator**	
3.12	Analyzing the symptoms of global warming and its impact on life and the environment.	3.12.1	Explain scientifically the phenomenon of global warming (LS K1)
		3.12.2	Evaluate & design scientific investigations on global warming (LS K2)
		3.12.3	Interpret/interpret scientific data & evidence regarding global warming (LS K3)
		3.12.4	Understand the problem of global warming (PM1)
		3.12.5	Make a settlement plan regarding global warming (PM2)
		3.12.6	Implement settlement plans regarding global warming (PM3)
		3.12.7	Check and evaluate the problem of global warming (PM4)
4.12	Proposing ideas/ideas to solve the problem of global warming in	4.12.1	Identify problems based on cases related to global warming
		4.12.2	Submit ideas/ideas to solve problems related to global warming experiments

Basic competencies		Indicator	
	connection with its symptoms and impacts on life and the environment.	4.12.3	Design a problem-solving strategy by collecting global warming experimental data
		4.12.4	Interpret/interpret global warming experimental data
		4.12.5	Presented the discussion results of the global warming experiment

b. Student Analysis

Steps of student analysis activities are carried out with the aim of examining the characteristics of students. Sampling for this study was based on recommendations from physics teachers at schools (purposive sampling). In analyzing the characteristics of students, an interview was conducted with the Physics teacher at MAN 2 Lamongan.

c. Task Analysis

Task analysis is carried out by detailing global warming material in outline form. The tasks that need to be carried out by students during the learning process are working on Student Worksheets (LKPD). Students can access and work on LKPD online through the link provided by the teacher during learning. The activities in the LKPD are in accordance with the stages of the problem-based learning model and are integrated with scientific literacy skills and problem solving regarding problem solving. The tasks that must be carried out by students at each meeting are as follows:

1) **The first meeting**: Students are oriented to the problems that exist in life related to the increasing temperature on the surface of the earth which is getting hotter and its relation to the greenhouse effect. In addition, students were shown data on increasing greenhouse gases (GHG). Then students solve problems through the stages of problem solving and designing scientific investigations through PhET Simulation experiments regarding the Greenhouse Effect. So that students through experiments are able to solve problems and can interpret data to present the data obtained.

2) **Second meeting**: Students are oriented to problems regarding environmental pollution that can trigger and spur global warming. In fact, environmental changes and global warming events in general are caused by human activities themselves. Human efforts in providing various conveniences of life such as wasteful use of electrical energy, use of air conditioners, waste disposal, etc. As a creative and innovative young generation, as well as in efforts to reduce the impact of global warming. Students create the concept of an eco-friendly dream house. Then students solve problems through the stages of problem solving, conducting literature studies, developing and presenting their work.

d. Concept/Material Analysis

The purpose of concept/material analysis is to find the most important and relevant information that needs to be taught, and organize it systematically.

e. Formulation of Learning Objectives

Learning objectives are formulated based on basic competencies and indicators in the 2013 curriculum. Based on KD 3.12, the learning objectives can be described as follows.

Table 3.2. Learning Goals

Indicator		Learning objectives	
3.12.1	Explain scientifically the phenomenon of global warming	3.12.1.1	Presented illustrated pictures about global warming, students can correctly identify problems related to the effects of global warming
		3.12.1.2	Presented pictures and narratives about the greenhouse effect, students can identify and evaluate the mechanisms related to the greenhouse effect appropriately
		3.12.1.3	Presented an article on climate change, students can analyze statements about global warming appropriately
		3.12.1.4	An article on global warming is presented, students can explain efforts to reduce GHG emissions which can increase global warming
3.12.2	Evaluate & design scientific investigations regarding global warming	3.12.2.1	Presented experimental data regarding the greenhouse effect, students can formulate problems related to the experiment correctly
		3.12.2.2	Presented experimental data regarding the greenhouse effect, students can identify the experimental variables from the experimental table correctly
		3.12.2.3	Presented the chemical formula of greenhouse gases and the average residence time of these gases in the atmosphere, students can identify and evaluate the types of greenhouse gases and their residence time in the atmosphere accurately.
3.12.3	Interpret/interpret scientific data & evidence regarding global warming	3.12.3.1	A narrative about an eco-friendly house is presented, students can analyze the criteria, benefits and advantages of an Eco-Friendly House correctly.
		3.12.3.2	Presented a carbon cycle, students can identify and analyze the carbon dioxide (CO2) cycle correctly.
		3.12.3.3	Literacy on greenhouses and the greenhouse effect is presented, students can evaluate facts about the greenhouse effect from an article correctly
		3.12.3.4	Presented table of increase in carbon dioxide, earth's temperature, and the amount of ice mass in the world. Students can interpret and analyze related data correctly.
3.12.4	Understand the problem of global warming	3.12.4.1	Presented problems regarding human activities that can increase GHG emissions, students can identify and formulate these problems correctly
		3.12.4.2	Presented problems regarding climate change, students can identify and formulate problems related to causes and efforts to overcome these problems properly
		3.12.4.3	Presented problems regarding the impact of burning waste, students can identify and formulate problems related to the right solutions to solve these problems correctly

		3.12.4.4	Presented experimental data of molecules and light, students can identify and formulate problems related to the role of gases in the experimental data correctly
3.12.5	Make a solution plan regarding global warming	3.12.5.1	Presented problems regarding human activities that can increase GHG emissions, students can formulate alternative strategies to solve these problems appropriately
		3.12.5.2	Presented problems regarding climate change, students can formulate alternative strategies for solutions related to causes and efforts to overcome these problems properly
		3.12.5.3	Presented problems regarding the impact of burning waste, students can formulate alternative strategies for solving the right solutions to solve these problems properly
		3.12.5.4	Presented experimental data of molecules and light, students can correctly formulate alternative solutions related to the role of gases in the greenhouse effect
3.12.6	Implement a settlement plan regarding global warming	3.12.6.1	Presented problems regarding human activities that can increase GHG emissions, students can provide decisions/solutions to these problems appropriately
		3.12.6.2	Presented problems regarding climate change, students can provide decisions/solutions related to causes and efforts to address these problems appropriately
		3.12.6.3	Presented problems regarding the impact of burning waste, students can provide decisions/solutions related to the right solutions to address these problems appropriately
		3.12.6.4	Presented experimental data of molecules and light, students can provide appropriate decisions/solutions regarding the role of these gases in the greenhouse effect
3.12.7	Examine and evaluate the problem of global warming	3.12.7.1	Presented problems regarding human activities that can increase GHG emissions, students can evaluate and re-check the process and results of solving problems that have been done correctly
		3.12.7.2	Presented problems regarding climate change, students can evaluate and re-check processes and results related to causes and efforts to overcome these problems properly.
		3.12.7.3	Presented problems regarding the impact of burning waste, students evaluate and re-check processes and results related to the right solutions to address these problems properly
		3.12.7.4	Presented experimental data of molecules and light, students can evaluate and re-check the processes and results related to the role of these gases in the greenhouse effect correctly.

2) Phase II: Design (Design)

At the design stage aims to design learning tools that will be developed. Curriculum analysis, student analysis, task analysis, content analysis, and learning objectives all influence the design of learning tools. The stages of this research design are as follows:

a. Test Preparation

As a link between the defining stage and the design. The test is a tool to determine whether there is a change in students after following the learning process. This research test was used to evaluate students' progress in scientific literacy and problem-solving skills.

b. Media Selection

The selection of media is based on task analysis, material analysis, student characteristics, and available facilities to find suitable and appropriate media in learning tools. In this study, one of the online media used, namely liveworksheets, WhatsApp Groups and the PhET Simulations virtual lab, became learning media.

c. Initial Design

The initial design in the development of learning tools is adjusted based on problem-based learning steps. The following is the design sequence of learning devices developed by researchers:

1. Syllabus

The revised 2013 curriculum forms the basis for syllabus development. The basic components, subject matter, and learning activities that must be completed by students according to the PBL learning model are included in the syllabus developed by the researcher. The syllabus contains in detail: a) Identification of subjects; b) school identity; c) core competencies. The following are the components that must be included in the table: a) basic skills; b) indicators; c) activities for learning; d) evaluation; e) main content; f) time allocation; also, g) learning assets.

2. Learning Implementation Plan (RPP)

The teacher's steps in learning activities are arranged in learning scenarios for each meeting in the learning implementation plan (RPP). RPP made as a learning guide which includes two meetings. The steps for teaching and learning activities have been adapted to the syntax of the PBL model, and the RPP that has been made is also in accordance with the revised 2013 curriculum.

3. *Handouts*

*Handouts*This is compiled from various literature related to global warming. set with lots of attractive illustrations and designs to entice learners to learn. Learners can learn more easily because they can access handouts online with a barcode or link.

4. Student Worksheets (LKPD)

Students use student worksheets as a guide to understand the material and complete experimental activities to address issues related to global warming. LKPD contains activities that must be carried out by students. LKPD-1 contains virtual experimental activities through the PhET Simulation application regarding the Greenhouse Effect problem and the output produced is in the form of works in the form of articles. In LKPD-2 is an experiment that contains problems regarding global warming and climate change and the output is in the form of posters regarding efforts to tackle global warming. LKPD can be accessed online so that it makes it easier for students to work on the problems presented.

5. Scientific literacy test and problem solving regarding global warming

The test used is an assessment sheet in the cognitive domain. The test questions are in the form of essays on global warming issues. The questions developed adhere to bloom taxonomy with cognitive processes C1 to C6. The knowledge test sheet contains basic competencies, indicators, and problem identification tables.

3) Stage III: Development (Develop)

The develop stage in this study aims to produce learning tools designed for use in physics teaching and learning activities, especially content related to global warming. The draft that has been prepared becomes the basis for the development stage which includes the following steps:

i. Device Validation by Experts/Experts

The learning tools developed will be tested in limited schools and validated with the help of experts. The validated tools include: syllabus, lesson plans, handouts, student worksheets, and evaluation sheets. The input generated from the revised results aims to improve existing learning tools. The expert review resulted in a revision of draft I, which led to draft II, which included suggestions for improvement to ensure the learning tools developed were practical and suitable for extensive testing or wide trials.

ii. Trial of Learning Devices

Class X MAN 2 Lamongan students will test Draft 2 after changes and validations are made by the validator. Limited trials were conducted with the aim of knowing the validity of the device empirically. The limited trial involved 1 class of students in class X. The expected result was that the developed learning tools could be used effectively to improve students' scientific literacy and problem solving skills. At this stage it is an activity to obtain initial data that will be used as a reference for further research.

Implementation of limited trials, researchers will be accompanied by several observers to observe the implementation of learning with learning tools that have been developed and observe the activities of students during the learning process takes place. The data obtained from the limited trial is used as a guide for improving learning tools, and can then be applied to the real class (wide trial).

Limited trials and wide trials were carried out using the One Group pre-test and post-test design. This design was used because this trial was carried out with only one group without a companion class (control class). The design in this study is described as follows:

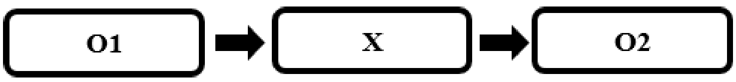


Figure 3.2. One Group Pre and Post-test Design

Information:

O1 : Giving pre-test questions to students (before learning using the developed learning tools)

X : Give treatment with TPACK integrated PBL learning

O2 : Give post-test questions as the final test to students

4) Stage IV: Dissemination (Disseminate)

At this stage, the steps for disseminating learning tools are in the form of articles published in national and international journals related to preliminary studies and research results obtained. The hope is that it can be used as a reference or guideline for developing physics or science learning through sustainable education for the sake of increasing the quality of education in Indonesia and the world. So, with good quality education, good human resources will also be created.

E. Research Variables

This development study has the following variables:

1. Validity, determining the validator of the validity value of the developed learning device.
2. Practicality is a measure of the ease of use of the device in terms of (1) the implementation of learning; (2) Activities for students; (3) Challenges faced during learning.
3. Effectiveness, which is a measure of whether the use of learning tools produces the expected results in terms of (1) Increasing students' scientific literacy and problem-solving skills; (2) positive response from students.

F. Definition of Variables

If a learning device meets the requirements for validity, usability, and effectiveness, it is said to be suitable for use.

1. Validity is the capacity to achieve what is expected, high precision, validity, and accuracy. The learning device validation sheet instrument which includes language, construct, and content validity is used to evaluate the learning device. The validity of the learning device is obtained by calculating the mode

value for each aspect which is assessed by 3 validators. The developed learning device is said to be valid if it has a value of ≥ 3.

2. The practicality of the device is measured by scores from observers who have made observations related to the implementation of learning, student activities in class, and obstacles encountered during learning. Practicality is defined as a measure of whether or not a device is easy to implement.

a) Implementation of Learning

The percentage of learning steps carried out by the teacher as outlined in the lesson plan is referred to as "learning implementation", and percentage$\geq$61% qualified "good". Learning implementation was assessed by two observers using the learning implementation sheet instrument.

b) Student Activity

The percentage of students involved in student activities during learning using the TPACK integrated PBL tool is referred to as "student activity". Student activity is assessed during the learning process and the value is adjusted according to the instrument used. Student activity is assessed by observers using student activity sheets.

c) Constraints / Barriers to Learning

The description of several things that do not go according to the lesson plan and can make it difficult for the smooth running of learning activities at each meeting is referred to as "learning constraints/obstacles". In addition to elaborating the obstacles related to learning, the next step is to provide alternative solutions to overcome each of these obstacles. These learning constraints were assessed by observers using the observation sheet instrument of learning constraints/obstacles.

3. Effectiveness is defined as an effective measure of whether or not the use of learning tools developed against the expected results. The effectiveness of learning devices is based on:

a) Student Science Literacy

The students' scientific literacy skills were obtained through a pre-test and post-test using the scientific literacy test instrument which consisted of 15 questions with five forms of questions. The material being tested is global warming. The increase in indicators of student literacy that is measured is: 1) explaining phenomena scientifically; 2) evaluating and compiling scientific investigations; and 3) interpret data and scientific evidence. The learning device on the students' scientific literacy test sheet is said to be effective if it has a minimum N-gain average in the moderate category.

b) Student problem solving skills

Problem solving skills possessed by students are obtained through a pre-test and post-test using a problem solving test instrument consisting of 5 questions. The indicators of problem solving skills include: 1) understand the problem; 2) make a plan (devise a plan); 3) Carry out the plan (carry out the plan); and 4) Looking back at the process and results (looking back). The learning device on the students' problem solving test sheet is said to be effective if it has a minimum N-gain average in the moderate category.

c) Student Response

The response of students is the reaction of students after learning using the developed learning tools. Learning devices are said to be effective if they get a positive response from students with a percentage of responses≥ 61 %(Good).

G. Research Instruments

The research instrument is a tool made by researchers to obtain data. The research instrument made is adjusted to the objectives to be achieved so that accurate data is obtained. Some of the instruments made by researchers include:

1. Learning Device Validity Assessment Instrument

a) Learning Device Validation Sheet

The validation sheet is used to assess the theoretical feasibility of the learning tools that have been developed. The learning device validation sheet instrument is used to examine the learning device developed so that it is truly feasible to use. Learning tools that are validated include, 1) Syllabus; 2) Learning Implementation Plan (RPP); 3) Handouts; 4) Student Worksheets (LKPD); and 5) Evaluation Sheet (LE). Learning tools are presented in Appendix 2.

The validation sheet instrument is to assess learning tools in terms of content, construct, and language by using an assessment rubik in the form of a rating scale. The validator then provides a general assessment of the tools that have been developed and makes a decision on whether the learning tools are suitable for use. Suitable for use with suggestions for improvement or not suitable for use (Appendix 3).

2. Learning Device Practicality Assessment Instrument

a) Learning Implementation Sheet

Learning implementation sheet to assess the steps of learning activities whether they are in accordance with the learning model applied or not. The form of this instrument is in the form of a table which contains the learning activities observed in accordance with the activities in the developed lesson plan with two answer choices for each aspect that is assessed, namely carried out or not carried out. If the activity is carried out, the observer gives an assessment score using a rating scale 1-4. The description of the implementation score is (1) = not good; (2) good enough; (3) good; and (4) very good. Instrument observation sheet implementation of learning is presented in Appendix 2.6.

b) Student Activity Observation Sheet

Student activity sheets are used to monitor or observe student participation during learning activities by applying the learning tools that have been developed. This observation sheet consists of 10 student action or activity statements and student activity scores. The student activity observation sheet instrument is presented in Appendix 2.7.

c) Student Barriers Observation Sheet

Observation sheets for students' obstacles are used to record obstacles/obstacles during the learning process. This observation sheet consists of two columns, namely the constraint column and the alternative solution column. Observers will note the constraints and alternative solutions as long as the teacher conducts learning in class using the learning tools that have been developed. Observation sheet instruments for students' obstacles are presented in Appendix 2.8.

3. Learning Device Effectiveness Assessment Instrument

a) Science Literacy Skills Assessment (KLS)

The scientific literacy skills assessment instrument (KLS) consists of 15 questions with five forms of questions regarding global warming material. The forms of scientific literacy questions are: 1) multiple choice (PG); 2) complex multiple choice (PGK); 3) true false (BS); 4) short entry (IS); and 5) matchmaking (M). Indicators of students' scientific literacy skills that are measured include: 1) explaining phenomena scientifically; 2) evaluating & designing scientific investigations; and 3) interpret/interpret scientific data & evidence. Students' KLS is tested as a pre-test and post-test and will later be analyzed using the assessment rubik that has been developed so that the score or increase in students' scientific literacy can be determined. Student scientific literacy test sheets are presented in Appendix 2.4a.

b) Problem Solving Skills Assessment (KPM)

The instrument for assessing students' problem solving skills (KPM) is in the form of 5 essay questions on issues related to global warming. Students' KPM is tested through pre-test and post-test. Based on the data from the pre-test and post-test results, it will later be analyzed through the assessment rubuk that has been developed so that the score or improvement in students' problem-solving skills can be known. The KPM indicators of students that are measured include: 1) understanding the problem; 2) make a settlement plan; 3) carry out the plan; and 4) checking and evaluating. Student problem solving test sheets are presented in Appendix 2.4b.

c) Student Response Assessment

This assessment instrument is a closed questionnaire in which the answer choices have been provided and are focused on the responses of students after participating in learning using the learning tools that have been developed. This student response questionnaire sheet uses an assessment rubric in the form of a rating scale. Students put a check mark on the statement that has been presented regarding the response after participating in the lesson. Answers in the form of strongly agree (SS), agree (S), disagree (TS), strongly disagree (STS). Student response sheet instruments are presented in Appendix 2.9.

H. Data Collection Techniques

The process of collecting data to determine the feasibility of learning tools that have been developed using the following techniques:

1. Validation Method

Validation of learning devices is carried out to obtain input, criticism and suggestions for the devices that have been developed. The validation results are then analyzed, if there is a revision, the device will be revised so that it becomes valid and suitable for use in research. The validation process is carried out using a validation sheet instrument that is prepared using closed assessment criteria and is accompanied by a choice of scores. The data to be obtained in the validation process is the validation score.

2. Observation Method

The purpose of the observation is to determine the feasibility of learning tools that have been developed in terms of practicality. Observational data includes:

a. Learning implementation data obtained from the observation method. The implementation of learning was observed by two observers during the implementation of the lesson plans. Each observer was given a learning implementation sheet. The observers were previously trained to fill out the learning implementation sheet. The RPP implementation observer sheet is in the form of an assessment table with each aspect of the assessment given a implementation and assessment column with a choice of scores 1-4 as well as comments or suggestions at the bottom of the table. The results of the assessment of the observers were taken on average to get the average for each aspect in the implementation of the lesson plans.

b. Student activity data obtained by observation techniques. Student activities were observed by two observers during the implementation of the lesson plan. Each observer was given a student activity sheet. Observers were previously trained to fill out student activity sheets. Student activity sheets are in the form of tables with each aspect of activity given a column to record student activity.

In addition, comments and suggestions are provided at the bottom of the student activity table.

c. Learning constraints data obtained through the observation method. Obstacles or learning obstacles were observed by two observers during the implementation of the lesson plan. Each observer was given a learning constraint sheet. The observers were previously trained to fill in the learning constraint sheet. The learning constraints observation sheet is in the form of a table with columns for the types of obstacles and alternative solutions that can be provided by the observer.

3. Test Method

The tests given consisted of two types of tests, namely tests of scientific literacy skills (KLS) and problem solving skills (KPM) of students. The test was given before (pretest) and after (posttest) the implementation of TPACK integrated PBL learning. The aim is to find out the increase in scientific literacy skills and problem solving of students after learning using the learning tools that have been developed.

4. Questionnaire Method

The questionnaire method is used to collect data about students' responses to PBL learning tools to improve scientific literacy and problem solving skills that have been developed and learning activities. Student responses to learning tools are needed to determine the feasibility of learning devices related to effectiveness.

I. Data Analysis Techniques

1) Learning Device Validity Analysis

Data analysis of the validity of the learning tools which included the syllabus, learning implementation plans, student worksheets, handouts, and evaluation sheets was carried out by three validators to provide an assessment of the learning tools being developed. Data validation results of learning devices were analyzed descriptively quantitatively by calculating the mode value of each aspect of the assessment of the three validators. The validation assessment score is shown in Table 3.3.

Table 3.3. Learning Tools Validation Rating Score

mode	Criteria	Information
4	Very Valid	Can be used without revision
3	Valid	Usable with minor revisions
2	Valid Enough	Can be used with multiple revisions
1	Invalid	Cannot be used and requires consultation

(Nizar, 2018)

A learning device is said to be valid if it has a mode score ≥ 3. Furthermore, the validator's assessment data can be determined by the reliability of the validation instrument. Reliability aims to determine the quality or stability of the measurement results. The equation used is using the Percentage of Agreement.

$$R(\%) = \left(1 - \frac{A-B}{A+B}\right) X\ 100 \quad (3.1)$$

Information:
R : Reliability coefficient
A : The score from the validator that gives the highest score
B : The score from the validator that gives the lowest score

The validation instrument is said to be reliable if it has a reliability value or has a percentage of agreement of more than 75% (≥ 0.75). (Sudirman, 2015).

2) Practicality Analysis of Learning Devices

a. Analysis of the implementation of learning

Two observers use observation sheets of learning implementation to evaluate learning. The average score obtained is used to determine the level of implementation of learning at each stage/phase. To find out the criteria for the level of implementation of learning, scores are presented in Table 3.4.

Table 3.4. Criteria Average Score

Score	Criteria
4	Very good
3	Good
2	Pretty good

Score	Criteria
1	Not good

(Patmawati, 2016)

The implementation of learning as a whole can be determined by calculating the score obtained by using the following equation.

$$Keterlaksanaan(\%) = \left(\frac{Skor\ yang\ diperoleh}{Skor\ maksimum}\right) X\ 100 \qquad (3.2)$$

The results of the calculation of the percentages above are then interpreted in Table 3.5 to determine the percentage of the implementation of learning that has been carried out using the developed learning tools.

Table 3.5. Learning Implementation Implementation Criteria

Percentage (%)	Criteria
0 – 20	Very bad
21–40	Bad
41–60	Enough
61–80	Good
81–100	Very good

(Riduwan, 2016)

b. Analysis of student activity

Student activities were observed by two observers where each observer wrote down a score for each student activity on the prepared instrument. Data on the results of student activities is known by calculating the percentage of activity from the frequency of students who carry out activities in accordance with the observed aspects. Score 1 for students who carry out activities according to the aspects observed and score 0 for students who do not. Then it is calculated using the percentage as follows.

$$Aktivitas\ (\%) = \frac{frekuensi\ aktivitas\ yang\ muncul}{total\ frekuensi\ aktivitas} \times 100 \qquad (3.3)$$

The results of the calculation of the percentages above are then interpreted in Table 3.6 to determine the percentage of participants' activity during learning activities using the developed learning tools.

Table 3.6. Criteria for Interpretation of Student Activities

Percentage (%)	Criteria
0 – 20	Very bad
21–40	Bad
41–60	Enough
61–80	Good
81–100	Very good

(Riduwan, 2016)

c. Analysis of constraints in learning

Researchers and observers provide notes on the constraints or obstacles that occur during the implementation of learning using the developed learning tools, as well as alternative solutions that can be applied to minimize or overcome these obstacles, in a qualitative descriptive analysis.

3) Analysis of the Effectiveness of Learning Devices

a. Analysis of Science Literacy Skills

Data on students' scientific literacy skills (KLS) related to the concept of global warming were obtained through a pre-test and post-test which referred to the developed assessment rubric. Before analyzing students' scientific literacy skills, an item analysis is carried out first. Item analysis aims to determine validity and reliability, level of difficulty, and discriminatory power. The software used to calculate the item analysis is using ANOTES V4. Analysis of instrument items or questions is carried out through 3 testing criteria, including:

(1) Test Item Reliability

Reliability analysis aims to determine the level of consistency of the questions used by researchers. So that the matter can be relied upon. The reliability of the items is classified in Table 3.7.

Table 3.7. Items Reliability Criteria

Reliability Value	Criteria
0.00 – 0.19	Very low
0.20 – 0.39	Low
0.40 – 0.59	Moderate
0.60 – 0.79	High

Reliability Value	Criteria
0.80 – 1.00	Very high

(Arikunto, 2016)

(2) Level of Difficulty of Items

Analysis of the level or level of difficulty (TK) of the question is to find out whether the question is classified as easy, medium or difficult. The level of difficulty of the items is classified in Table 3.8.

Table 3.8. Item Difficulty Level Criteria

Kindergarten grades	Criteria
0.00 ≤ Kindergarten ≤ 0.30	Difficult
0.31 ≤ Kindergarten ≤ 0.70	Moderate
0.71 ≤ Kindergarten ≤ 1.00	Easy

(Arikunto, 2016)

(3) Item Difference Power

The differentiating power analysis (DP) of the items aims to determine the extent to which the items are able to distinguish students who have not or have mastered certain competencies. The criteria for different power of questions are classified in Table 3.9.

Table 3.9. The Criteria for Discriminating Items

DP value	Criteria
Negative sign	Items have very poor discrimination
0.00 – 0.20	Items have weak discrimination
0.21 – 0.40	Items have moderate discrimination
0.41 – 0.70	Items have good discrimination
0.71 – 1.00	Items have very strong differentiating power

(Arikunto, 2016)

Next, that is analyzing the pre-test and post-test data. Before analyzing the significance between the pre-test and post-test values, an assumption test was carried out first, namely the normality and homogeneity tests to determine the type of inferential statistics used. Researchers used SPSS 25 software to analyze statistical data.

The normality test aims to determine whether the distribution of data is normally distributed or not. In the normality SPSS, you can use the Kolmogorov-Smirnov and Shapiro-Wilk tests. The basis for decision making on the normality test is:

(a) If the significance value (Sig.) is greater than 5% or (> 0.05), then the research data is normally distributed (H0 is accepted).
(b) Conversely, if the significance value (Sig.) is less than 5% or (<0.05), the research data is not normally distributed (H0 is rejected).

The homogeneity test aims to determine whether the research sample has the same (homogeneous) variance or not. The basis for making a decision on the homogeneity test is:

(a) If the significance value (Sig.) is greater than 5% or (> 0.05), then it is said that the variances of two or more population data groups are the same or homogeneous (H0 is accepted).
(b) If the significance value (Sig.) is less than 5% or (<0.05), then it is said that the variances of the two or more population data groups are not the same or not homogeneous (H0 is accepted).

If the research data are normally distributed, then carry out a comparative test or comparative test to determine the significance of the pre-test and post-test values in the paired samples test. If the data is not normal, it will be analyzed using non-parametric analysis with the Wilcoxon test. The basis for decision making in the paired sample t-test and Wilcoxon test in SPSS is as follows:

(a) If the value of Sig. (2-tailed) is greater than 5% or (> 0.05), then H0 is accepted and Ha is rejected. This means that there is no significant difference in the average value of the pre-test and post-test.
(b) If the value of Sig. (2-tailed) less than 5% or (<0.05), then H0 is rejected and Ha is accepted. This means that there is a significant difference in the average value of the pre-test and post-test.

Furthermore, to test the difference in the average data for more than two groups, the ANOVA test (analysis of variance) was used. One Way ANOVA can be done if the data assumptions are met, that is, the data has a homogeneous variance. If the assumptions are not met, the alternative is to use the Kruskal Wallis test. The basis for decision making is:

(a) If the significance value (Sig.) is greater than 5% or (> 0.05), then there is no significant difference in the average student score based on the group or research sample (H0 is accepted and Ha is rejected).

(b) If the significance value (Sig.) is less than 5% or (<0.05), then there is a significant difference in the average score of students based on the group or research sample (H0 is rejected and Ha is accepted).

After knowing the significance between the pre-test and post. This difference can be analyzed using the average normalized gain using the following equation.

$$< g >= \frac{Skor\ posttest - Skor\ pretest}{100 - skor\ pretest} \quad (3.4)$$

The gain scores obtained can then be categorized based on Table 3.10, namely:

Table 3.10. Criteria for N-Gain Score

Percentage	**Criteria**
$(<g>) \leq 0.3$	Low
$0.3 < (<g>) \leq 0.7$	Moderate
$(<g>) \geq 0.7$	High

b. Problem Solving Skills Analysis

Data on students' scores related to problem-solving skills were also obtained through pre-test and post-test scores that referred to the developed assessment rubric. The steps, equations, and decision-making process of the data analysis technique are identical to the analysis of scientific literacy skills discussed earlier (top).

c. Analysis of Student Response Results

The questionnaire given to students was in the form of questions related to responses after participating in learning using the developed learning tools. The response answers are in the form of answer choices that strongly agree, agree, disagree, and strongly disagree. Student responses were analyzed descriptively quantitatively using the following equation.

$$Respon\ (\%) = \frac{Skor\ yang\ diperoleh}{Skor\ maks} \times 100 \quad (3.5)$$

The percentages obtained are then interpreted using the student response criteria in Table 3.11.

Table 3.11. Student Response Criteria

Percentage (%)	**Criteria**
0 - 20	Very less
21 - 40	Not enough
41-60	Enough
61 - 80	Good
81 - 100	Very good

(Ridwan, 2015)

J. The Research Method Matrix

The research method matrix is a brief description of the research which includes research objectives, research variables, operational definitions of research variables, research instruments, data sources, data collection techniques, and data analysis. Table 3.12 describes the matrix of this research method.

Table 3.12. The Research Method Matrix

No	Research purposes	Research variable	Variable Operational Definitions	Research Instruments	Data source	Data collection technique	Data analysis
1.	**The validity of the learning tools that have been developed**						
	a. Describe the validity of learning tools that have been developed	Learning device validity	Learning devices are assessed using learning device validation sheet instruments which include aspects of content validity, constructs, and language	Syllabus, RPP, Handout, LKPD, LE validation sheet (scientific literacy and problem solving ability test)	Expert Validator	Filling in the validation sheet	Quantitative descriptive
2.	**Practicality of learning tools that have been developed**						
	a. Describe the implementation of learning	Learning Implementation Plan (RPP)	The level of implementation of learning in each phase and the percentage of implementation carried out by the teacher during learning takes place	Observation sheet / observation of learning implementation	Observer	Observation	Quantitative descriptive

No	Research purposes	Research variable	Variable Operational Definitions	Research Instruments	Data source	Data collection technique	Data analysis
	b. Describe the activities of students during the learning	Student activity	Activities carried out by students during learning activities	Student activity observation sheet	Learners	Observation	Quantitative descriptive
	c. Describe the obstacles encountered during the implementation of learning	Obstacles encountered during implementation	Obstacles / field constraints encountered during learning	Obstacle observation sheet in the field	Teachers, students, and observers	Observation	Qualitative descriptive
3.	**The effectiveness of learning tools that have been developed**						
	a. Describe students' scientific literacy skills	Students' scientific literacy skills	Indicators of scientific literacy skills include: 1) Explain phenomena scientifically 2) Evaluating & designing scientific investigations 3) Interpret/interpret scientific data & evidence	Science literacy skills test	Learners	Test administration	▪ Quantitative descriptive ▪ *Paired samples t-testt* or Wilcoxon
	b. Describe students' problem solving skills	Problem solving skills	Indicators of problem solving skills include: 1) Understanding the problem 2) Create a settlement plan	Problem solving skills test	Learners	Test administration	▪ Quantitative descriptive ▪ *Paired samples t-*

No	Research purposes	Research variable	Variable Operational Definitions	Research Instruments	Data source	Data collection technique	Data analysis
			3) Carry out the plan 4) Check and evaluate				*test*t or Wilcoxon
	c. Describe the responses of students after participating in learning using the developed learning tools	Student response	Responses were in the form of opinions and responses regarding the benefits and motivation of students towards the implementation of the development of TPACK integrated problem-based learning learning tools	Student response questionnaire	Questionnaire filling	Questionnaire filling	Quantitative descriptive

CHAPTER IV
RESEARCH RESULTS

This chapter presents the results of research on the development of TPACK-integrated Problem Based Learning learning tools to improve students' scientific literacy and problem solving skills on global warming material. The results of this learning device development research include: (1) validity, which is viewed from the aspects of content, construct, and language; (2) practicality, which is seen from the implementation of learning, obstacles/obstacles, and student activities; and (3) effectiveness, in terms of increasing scientific literacy and problem solving skills, as well as participants' responses after learning with the developed tools. The following are the results of the research that has been done.

A. Results of Learning Tool Validation

Learning tools developed include: syllabus, lesson plans, handouts, worksheets, and evaluation sheets (LE). The learning instrument created was approved and validated by three expert validators. The development of learning tools is validated to ensure the terms of content (content), construct (presentation), and language. The research results obtained are in the form of validation assessment scores and input (suggestions), so that they can be used as a reference for improving the learning tools that have been developed. The following presents the results of the validation of each component of the learning device.

1) Syllabus Validation Results

The syllabus is one of the references for compiling a learning framework in each subject study material. Complete syllabus validation is presented in Table 4.1 which has been obtained from three validators based on Appendix 3.

Table 4.1. Results of Syllabus Validation

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
A. Identity							
1	Completeness of writing identity syllabus	2	3	3	3	80.00	V

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
2	Compatibility of core competencies with the curriculum	4	4	4	4	100.00	SV
3	Compatibility of basic competencies with the curriculum	4	4	4	4	100.00	SV
B. Learning Activities							
1	Conformity of indicators formulated with basic competencies	4	4	4	4	100.00	SV
2	Conformity of learning activities with indicators	4	4	4	4	100.00	SV
3	The suitability of learning activities developed with problem based learning using the TPACK approach	4	3	4	4	85.71	SV
4	Learning activities contain indicators of scientific literacy and problem solving skills	4	4	3	4	85.71	SV
5	Determination of learning activities supports students for active learning	4	4	4	4	100.00	SV
6	Appropriateness of time allocation to achieve the formulated indicators	2	4	3	-	66,67	
C. Tools, Resources, Media							
1	Appropriateness of tools, resources, and media used with learning materials.	4	4	4	4	100.00	SV
2	Appropriateness of tools, resources, and media used to achieve learning indicators	4	4	4	4	100.00	SV
D. Assessment							
1	Suitability of indicators with the type of assessment	4	4	4	4	100.00	SV
2	Appropriateness of the type of knowledge assessment with the learning objectives to be achieved	4	3	4	4	85.71	SV
3	Appropriateness of the type of skills assessment with the learning objectives to be achieved	4	4	4	4	100.00	SV
E. Language Use							
1	The use of standard words in learning devices	3	4	4	4	85.71	SV

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
2	The use of words is clear, easy to understand and communicative	3	4	4	4	85.71	SV
Syllabus Mode and Category					**4**	**92,20**	**SV**

Information:
V1: Validator 1, V2: Validator 2, V3: Validator 3, V: Valid, SV: Very Valid

The results of the validator's assessment of each aspect of the syllabus in Table 4.1 show that the mode of syllabus validation results is in a very valid category. The percentage of agreement or the percentage of compatibility by the three validators in all aspects of the syllabus is 92.20%, meaning that the syllabus as a whole (content, presentation, and language) is declared reliable. However, the assessment at number 6 on learning activities is stated to be unreliable. This is caused by the time listed on the syllabus is too short to complete all the learning objectives that are formulated.

Table 4.2 contains feedback provided by the validator regarding the researchers' efforts to improve syllabus development.

Table 4.2. Validator's Suggestions for the Syllabus

No	Validator's Suggestion	After Revision
1.	Need to add cover, preface, table of contents, and bibliography on the learning device	The researcher added a cover, preface, table of contents, and bibliography to the learning device
2.	Need to complete the identity on the Syllabus	Researchers add and complete the identity that is lacking in the syllabus
3.	The table needs to be set to "Repeat Header Rows"	The researcher fixed the table layout on the syllabus
4.	Time allocation needs to be adjusted again to achieve the formulated learning objectives	Researchers adjust the time with the formulated learning objectives

2) Learning Implementation Plan Validation Results (RPP)

Guidelines that are arranged systematically according to the specified learning model are known as Learning Implementation Plans (RPP). The lesson plan in this study consisted of two meetings with 2 JP each, where 1 JP equals 2 x 45 minutes. A recap of the results of the assessment of the learning plan by the validator is presented in Table 4.3.

Table 4.3. Results of the Validation of the Learning Implementation Plan

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
A. RPP identity							
1	Format for writing RPP identity (education unit, subject, class, semester, subject matter, time allocation)	3	4	4	4	85.71	SV
B. Formulation of KI, KD and Indicators							
1	Completeness of core competency writing	4	4	4	4	100.00	SV
2	Completeness of basic competency writing	4	4	4	4	100.00	SV
3	Completeness of writing indicators	3	3	3	3	100.00	V
4	The use of operational verbs in indicators	4	4	4	4	100.00	SV
5	Conformity between indicators with basic competencies	4	4	4	4	100.00	SV
C. Formulation of Learning Objectives							
1	Completeness of writing learning objectives in the ABCD format	4	4	4	4	100.00	SV
2	Conformity between the learning objectives with the indicators formulated	4	4	4	4	100.00	SV
D. Selection of Learning Materials & Methods							
1	The accuracy of the concept of the material discussed	3	3	4	3	85.71	V
2	The suitability of the material with the specified time allocation	3	4	3	3	85.71	V
3	The approaches, models, and methods used are in accordance with the characteristics of the students	3	4	4	4	85.71	SV
E. Learning Activities							
1	Clarity of learning stages (introduction, core, closing)	4	4	3	4	85.71	SV
2	The use of learning syntax is in accordance with the problem-based learning phase with the TPACK approach	4	3	4	4	85.71	SV

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
3	Appropriateness of the contents of learning activities with the objectives of learning scientific literacy and problem solving	4	4	3	4	85.71	SV
4	Provision of time allocation in each stage of learning	4	4	3	4	85.71	SV
F. Language							
1	Grammatical correctness	3	4	4	4	85.71	SV
2	Accurate sentence structure	3	4	4	4	85.71	SV
3	The language used is communicative	4	4	4	4	100.00	SV
RPP Mode and Category					**4**	**92.06**	**SV**

Information:
V1: Validator 1, V2: Validator 2, V3: Validator 3, V: Valid, SV: Very Valid

The results of the validator's assessment of each aspect of the RPP in Table 4.3 show that the mode of RPP validation results is in the very valid category. The percentage of agreement or the percentage of conformity by the three validators in all aspects of the lesson plan is 92.06%, meaning that the overall plan (content, presentation, and language) is declared reliable. So that RPP is relevant to use in designing learning and can be accounted for scientifically.

Table 4.4 contains the feedback provided by the validator regarding the researchers' efforts to improve lesson plan development.

Table 4.4. Validator's Suggestions for Learning Implementation Plans

No	Validator's Suggestion	After Revision
1.	Learning indicators are directed to the skills being trained (Scientific literacy and problem solving skills)	Researchers improve learning indicators that lead to students' scientific literacy skills and problem solving
2.	The TPACK approach is more prominent in learning activities	Researchers include or bring up the TPACK components in learning activities
3.	Time allocation needs to be adjusted again to achieve the formulated learning objectives	Researchers adjusted the time with the formulated learning objectives

No	Validator's Suggestion	After Revision
4.	The table needs to be set to "Repeat Header Rows"	The researcher fixed the layout on the learning activity table

3) Handout Validation Results

Student handout handouts serve as a reference for classroom learning activities and independent learning. The handout contains global warming material with the TPACK integrated problem-based learning model. The results of the handout validation developed can be seen in Table 4.5.

Table 4.5. Handout Validation Result Data

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
A. Presentation of Material							
1	The accuracy of the use of the concept in the presentation of the material	4	4	4	4	100.00	SV
2	The depth of the material covered in the handout	3	4	3	3	85.71	V
3	The ability to stimulate students' deep thinking through illustrations and practice questions	4	3	4	4	85.71	SV
4	Conformity / accuracy of the image with the material	4	4	4	4	100.00	SV
5	Completeness of image identification	4	4	4	4	100.00	SV
6	Relevance of material with problems in real life	4	4	4	4	100.00	SV
B. Contents							
1	The suitability of the material with the curriculum	4	4	4	4	100.00	SV
2	The correctness and completeness of the content (facts, concepts, theories, and principles) used	3	4	4	4	85.71	SV
3	Conformity of the examples presented with everyday life	4	4	4	4	100.00	SV
D. Language							
1	The suitability of the language used with the rules of Indonesian	3	4	3	3	85.71	V

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
2	Clarity of sentence intent on the handout	4	3	4	4	85.71	SV
3	The accuracy of the use of terms / words and symbols	3	4	4	4	85.71	SV
Handout Mode and Category					**4**	**92.86**	**SV**

Information:
V1: Validator 1, V2: Validator 2, V3: Validator 3, V: Valid, SV: Very Valid

The results of the validator's assessment of each aspect of the handout in Table 4.5 show that the mode of the handout validation results is in the very valid category. The percentage of agreement or the percentage of agreement by the three validators in all aspects of the handout was 92.86%, meaning that the handout as a whole (content, presentation, and language) was declared reliable. So that relevant handouts are used to support learning and can be accounted for.

Table 4.6 contains feedback provided by the validator regarding the researchers' efforts to improve the handout development.

Table 4.6. Validator's Suggestions for Handouts

No	Validator's Suggestion	After Revision
1.	Need to improve the writing and completeness of the title on the cover handout	The researcher completes the cover title by including the integration of TPACK and the skills being trained
2.	Need to add contextual phenomena	Researchers add contextual phenomena to the topic of the greenhouse effect and global warming
3.	It is necessary to include student worksheets in the handout	The researcher added a student worksheet link to the handout
4.	It is necessary to add a discussion about scientific literacy to the practice questions in the handout	Researchers added practice questions regarding scientific literacy and problem solving

4) Student Worksheet Validation Results (LKPD)

The LKPD being developed is the LKPD with the PBL model with the TPACK approach to train students' scientific literacy and problem-solving skills. LKPD consists of LKPD 1 (The greenhouse effect) and LKPD 2 (Eco-friendly house). The results of LKPD validation by the three validators obtained are presented in Table 4.7.

Table 4.7. Validation Results of Student Worksheets

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
A. Construction							
1	The clarity and legibility of the figures and tables presented	4	4	4	4	100.00	SV
B. Contents							
1	Conformity of activities on LKPD with KD.	4	4	4	4	100.00	SV
2	Conformity of activities on LKPD with objectives.	4	4	4	4	100.00	SV
3	Clarity of intent so as not to create multiple interpretations	4	4	4	4	100.00	SV
4	Clarity in the formulation of work instructions for LKPD	4	4	4	4	100.00	SV
D. Language							
1	The suitability of the language used with the rules of Indonesian	3	4	4	4.00	85.71	SV
2	Formulation of sentences in communicative questions	4	4	3	4.00	85.71	SV
3	Use language that is easily understood by students	4	3	4	4.00	85.71	SV
LKPD Mode and Category					**4.00**	**94.64**	**SV**

Information:
V1: Validator 1, V2: Validator 2, V3: Validator 3, V: Valid, SV: Very Valid

The results of the validator's assessment of each aspect of the LKPD in Table 4.7 show that the mode of LKPD validation results is in the very valid category. The percentage of agreement or the percentage of conformity by the three validators in all aspects of the LKPD is 92.64%, meaning that the LKPD validation sheet as a whole (content, presentation, and language) is declared reliable. So that the relevant LKPD is used to support learning and can be accounted for scientifically.

Table 4.8 contains feedback provided by the validator regarding researchers' efforts to improve the development of LKPD.

Table 4.8. Validator Suggestions for Student Worksheets

No	Validator's Suggestion	After Revision
1.	It is necessary to align the objectives of the LKPD with the learning objectives of the RPP	Researchers aligned the goals of the LKPD with the learning objectives in the lesson plans
2.	The problems raised in the LKPD need to be emphasized in the introduction	Researchers fix the problems presented in the introduction in each LKPD
3.	It is necessary to add a discussion regarding scientific literacy from problems in LKPD	The researcher added a discussion about scientific literacy in each LKPD

5) Assessment Sheet (LE)

The assessment sheet is an instrument used for assessing student learning outcomes. The assessment sheets for the learning tools developed consisted of two types of questions, namely AKM-based multiple choice questions to measure scientific literacy skills and essay questions to measure students' problem-solving skills. Table 4.9 is the result of the validation of the score sheet by three validators.

Table 4.9. Results of the Assessment Sheet

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
A. Construction							
1	The clarity and legibility of the images, graphs and tables presented	4	3	4	4	85.71	SV
2	Using question words or demanding commands	4	4	3	4	85.71	SV
B. Contents							
1	Conformity of questions with indicators of scientific literacy and problem solving.	4	4	4	4	100.00	SV
2	The contents of the material asked are in accordance with the	4	4	4	4	100.00	SV

No	Aspect	Validators			mode	R (%)	Category
		V1	V2	V3			
	level of the type of school or class level						
3	Clarity of the meaning of the questions given	4	3	4	4	85.71	SV
4	Clarity in the formulation of instructions for working on questions	4	4	4	4	100.00	SV
5	The clarity and suitability of the questions with the answers and the assessment guideline rubric	4	4	3	4	85.71	SV
D. Language							
1	The suitability of the language used with the rules of Indonesian	3	4	4	4	85.71	SV
2	Formulation of sentences in communicative questions	4	4	3	4	85.71	SV
3	The clarity of the question sentence so that it does not contain multiple meanings	4	3	4	4	85.71	SV
4	Use language that is easily understood by students	4	4	4	4	100.00	SV
LE Mode and Category						**90,91**	**SV**

Information:
V1: Validator 1, V2: Validator 2, V3: Validator 3, V: Valid, SV: Very Valid

The results of the validator's assessment of each aspect of LE in Table 4.9 show that the mode of the LE validation results is in a very valid category. The percentage of agreement or the percentage of conformity by the three validators in all aspects of LE is 90.91%, meaning that the LE validation sheet as a whole (content, presentation, and language) is declared reliable. So that LE is relevant to use for test sheets to measure students' skills and can be accounted for scientifically.

Table 4.10 contains feedback provided by the validator regarding the researchers' efforts to improve the development of the evaluation sheet.

Table 4.10. Validator's Suggestions for Evaluation Sheets

No	Validator's Suggestion	After Revision
1.	Questions to measure students' scientific literacy and problem solving skills must be separated	Researchers fix the questions, with different forms of questions for

No	Validator's Suggestion	After Revision
		scientific literacy tests and problem solving.
2.	Writing is corrected	The researcher fixed the writing and layout on the evaluation sheet
3.	Consistency of indicators on syllabus, lesson plans, worksheets, and evaluation sheets	The researcher equates the indicators on the evaluation sheet with the RPP and LKPD
4.	Image sources need to be listed	Researchers include sources on the pictures on the evaluation sheet

B. The practicality of learning tools

The practicality of the learning tools that have been developed are based on the implementation of learning, the constraints/obstacles encountered during the learning process, and the activities of students. The details are explained in the following sections:

1. Implementation of Learning

The implementation of this study was assessed by two observers at each meeting. The first observer was a physics teacher at MAN 2 Lamongan (Nurul Masfufah, M.Pd.) and the second observer was a research partner (Pristiwati Yudha Hana, S.Pd.). Observation of the implementation of learning describes the implementation of teacher activities listed in the lesson plans that have been developed. The teacher applies the learning tools that have been developed by conducting learning for two meetings, with the TPACK integrated problem-based learning model. Learning at the first meeting was carried out face to face and the second meeting was carried out online.

The recapitulation of learning implementation scores is presented in Appendix 4.1. It can be seen that the average percentage of the implementation of learning from the three classes at the first meeting was 85.12% with a very good category, while at the second meeting the average learning implementation of the three classes was 87.23% with a very good category as well. Figure 4.1 shows a diagram of the average percentage of learning implementation in each class.

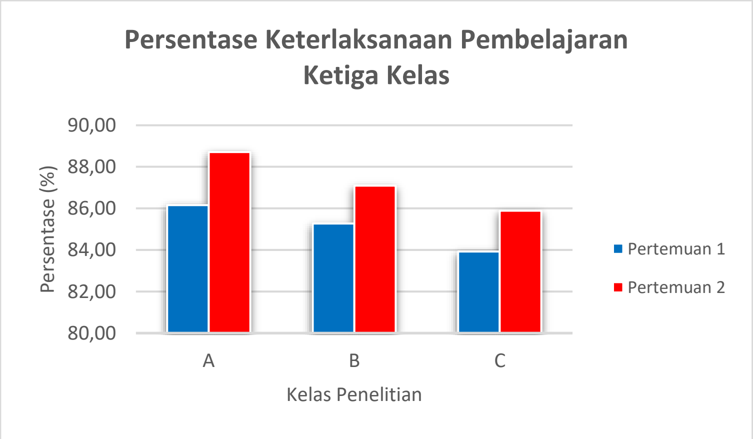


Figure 4.1. Percentage of Implementation of Learning from the Three Classes

Based on Figure 4.1, it can be seen that the assessment of the implementation of learning by observers in class A has the highest percentage of implementation of the other classes. At the first meeting the percentages from highest to lowest were class A (86.16%), class B (85.27%), and class C (83.93%). At the second meeting, there was an increase in the implementation of learning. The percentages of the three classes from lowest to highest respectively are class C (85.89%), class B (87.10%), and class A (88.71%). The implementation category in the three classes, in the first and second meetings was in the very good category. Furthermore, it can be identified the implementation of learning as a whole in each class, which is presented in Figures 4.2 to Figure 4.4.

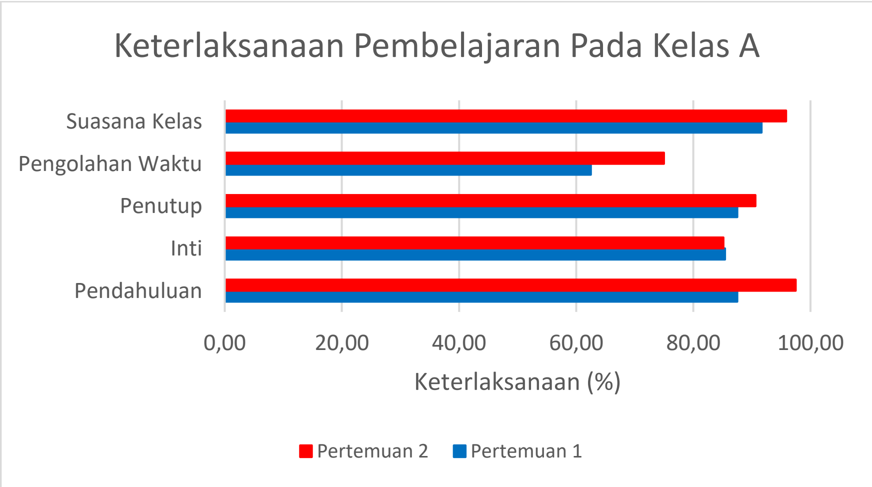


Figure 4.2. Diagram of Class A Learning Implementation

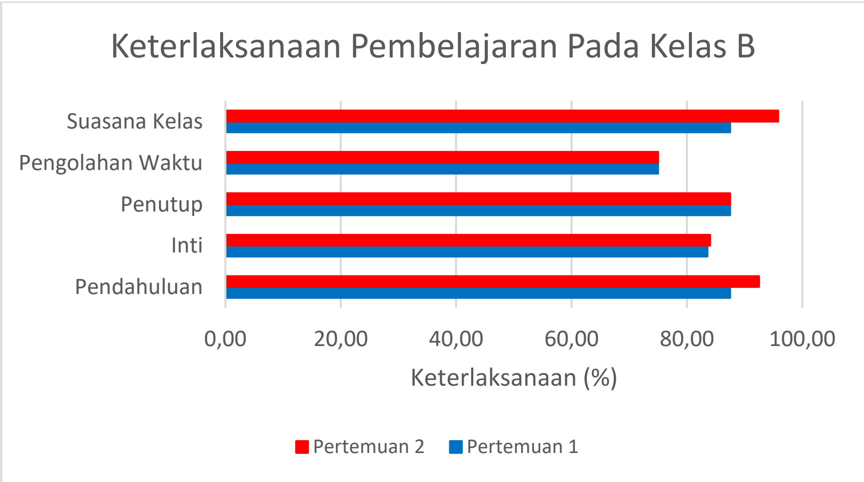


Figure 4.3. Diagram of Class B Learning Implementation

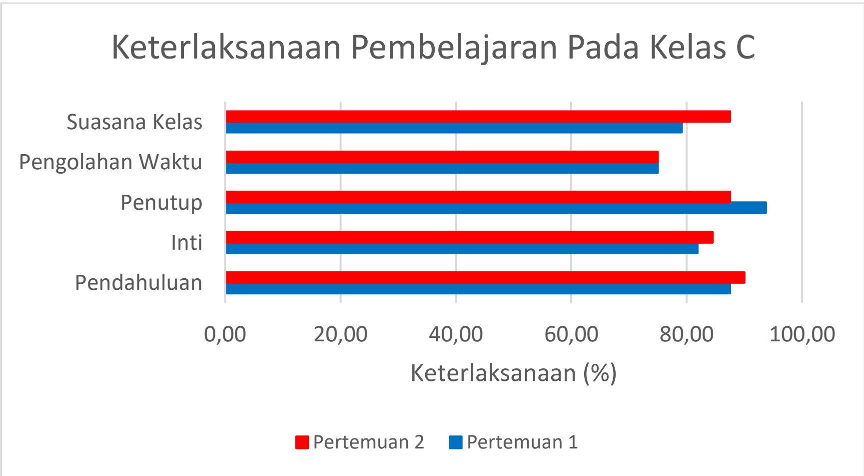


Figure 4.4. Diagram of Class C Learning Implementation

In Figure 4.2 to Figure 4.4, it presents the implementation of learning in detail, namely preliminary activities, core, closing, processing time and class atmosphere. The core activities consist of five learning phases according to the phases in the learning model used, namely problem-based learning. Phase I is the orientation of students on the problem; Phase II is organizing students to learn; Phase III is guiding individual/group experiences; Phase IV, namely developing and presenting the work; and Phase V analyzes and evaluates the problem solving process.

In Figure 4.2, it can be identified that in class A the first meeting the average percentage of implementation sequentially, namely introduction (87.50), core activities (85.42), closing (87.50), processing time (62.50), and atmosphere class (91.67). At the second meeting the average percentage of learning implementation was highest to lowest, namely introduction (97.50), class atmosphere (95.83), closing (90.63), core activities (85.13), and processing time (75.00).

Figure 4.3 shows that in class B at the first meeting, the average percentage from lowest to highest is time management (75.00), core activities (83.54), introduction, closing, and class atmosphere (87.50). At the second meeting the average percentage of learning activity implementation was highest to lowest, namely class atmosphere (95.83), introduction (92.50), closing (87.50) and core activities (84.04), and processing time (75.00) .

In Figure 4.4, it is known that in class C at the first meeting the average percentage of implementation from highest to lowest was successive, namely closing (93.77), introduction (87.50), core activities (81.88), class atmosphere (79.17), and processing time (75.00). At the second meeting, learning activities from lowest to highest were time processing (75.00), core activities (84.50), closing and class atmosphere (87.50), and introduction (90.00).

The percentage of implementation of learning in the core learning activities or each phase of the problem-based learning model is presented in Figure 4.5. It can be seen that in phase I, the highest average percentage of learning implementation occurred in class A and B (83.33) with very good implementation category and in good category in class C (79.17). In phase II, the three classes had a very good average performance, with the highest percentage to the lowest successively, namely class A (92.19), B (87.50), and C (85.94). In phase III, the percentage of superior implementation was in class A (83.33) and followed by class B and C (81.25) with all three being in the very good category. In phase IV, the percentage of implementation has the same average in class A and C (82.08) and the highest occurs in class B (86.67). The last phase is phase V, the three classes had very good implementation percentages, namely class A (85.43), B (84.38), and C (83.33). So it can be concluded that the percentage of implementation in the three classes based on the PBL phase is in the very good implementation category.

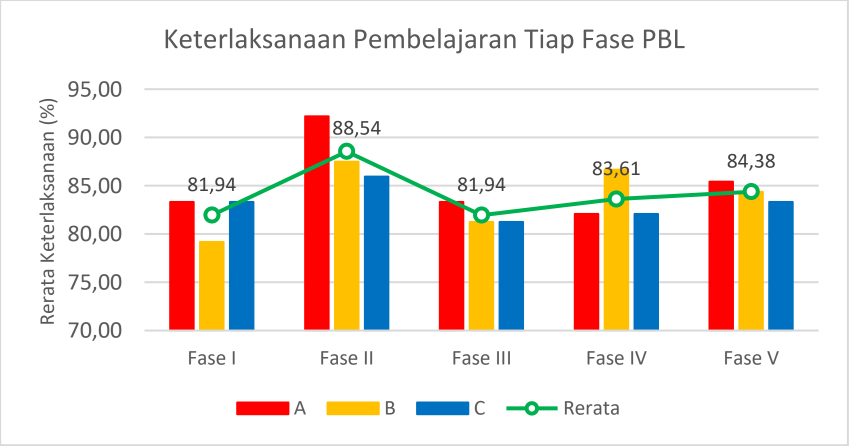


Figure 4.5. Diagram of Learning Implementation for Each Phase of PBL

2. **Student Activity**

Student activity is the behavior of students during the learning process. Student activities in observed learning include: 1)Hearing and observing the motivation, apperception, and goals conveyed by the teacher; 2) Understand the problem and be able to explain phenomena scientifically; 3) Reading handouts or looking for information on teaching materials according to the content; 4) Planning settlements and scientific investigations; 5) Implement plans and evaluate; 6) Working on LKPD and designing works; 7) Working together with groups; 8) Interpret or interpret data and evidence scientifically; 9) Check and evaluate the work; and 10) Asking or responding to questions. Recapitulation of student activity data during the two meetings is presented in Appendix 4.2. Figure 4.6 is the percentage of student activity from the three classes at the first meeting.

Figure 4.6. Diagram of Student Activity in the First Meeting

Based on Figure 4.6, it can be seen that the activities of students in the three classes have good and very good categories. In class A, the activities of students who have a very good category, namely the points observed are 1, 3, 6, 7, and 10 and activities in the good category, namely at points 2, 4, 5, 8, and 9. Class B, the percentage of student activity that has a very good category, namely at points 1, 6, 7, and 10 and activities in the good category, namely at points 2, 3, 4, 5, 8, and 9. In class C, at points 1, 3 , 6, 7, 9, and 10 have a very good category of activity percentage and points 2, 4, 5, and 8 are in the good category. The average percentage of implementation of the class with the highest to the lowest percentage value respectively is class A (81.88), class C (79.44), and class B (78.00).

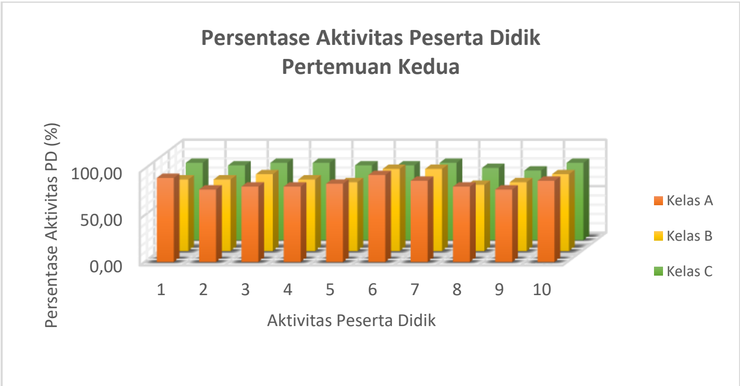


Figure 4.7. Student Activity Diagram at the Second Meeting

In Figure 4.7, it is known that in class A, the percentage of student activity at the observed points number 2 and 9 is in the good category and the other points are in the very good category. In class B, the percentage of student activities in the very good category is at points 3, 6, 7, and 10 and the activities of students who get good categories are at points 1, 2, 4, 5, 8, and 9. Class C, the percentage of student activity is all in the very good category, except for the activity at points 8 and 9. Overall the aspects or points observed, the average percentage of student activity that has a very good activity category is in class A (84.38) and class C(81,11). The results of student activities as a whole are briefly illustrated in Figure 4.8.

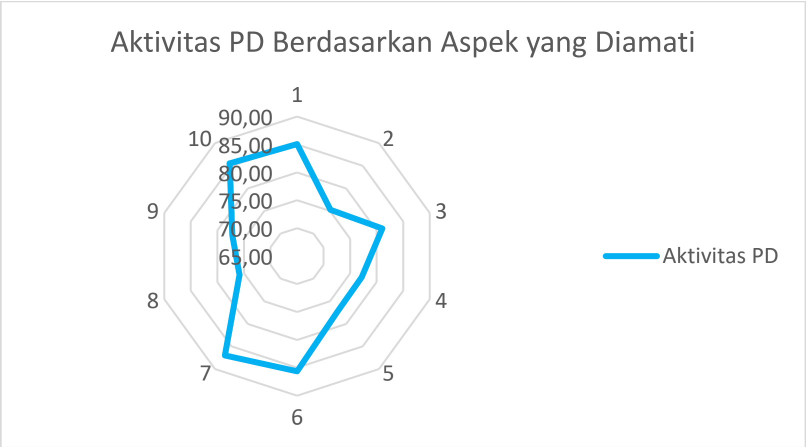


Figure 4.8. Student Activity in Each Aspect Observed

Based on Figure 4.8, it can be analyzed that the top three participant activities that have the highest percentage are working with groups (point 7) of 86.98%, working on worksheets and designing works (point 6) of 85.63%, and asking or responding to questions (point 10) of 85.55%. Student activities with the three lowest percentages are at point 2 (understanding the problem and being able to explain phenomena scientifically) at 75.22%, at point 8 (interpreting/interpreting data and evidence scientifically) at 75.85%, and at point 4 (planning completion and scientific investigation) of 77.19%. The percentage of student activity during learning as a whole based on the observed aspects is in the good and very good categories.

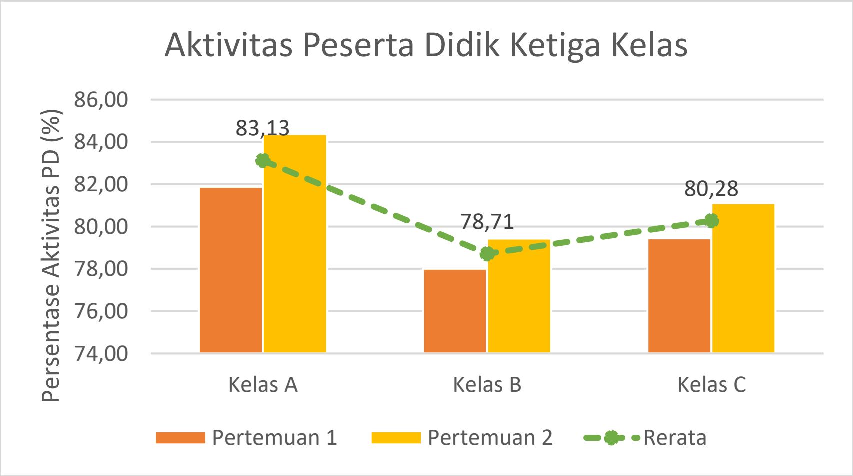


Figure 4.9. Diagram of Percentage of Student Activity

In Figure 4.9 above, it presents the average percentage of student activity in each class and meeting. It is known that, overall the activities of students during learning are in the very good category (80.71) with details of the highest to lowest percentage values of the three classes, namely class A (83.13), C (80.28), and B (78,71). Class B has less activity in learning than other classes (classes A and C). This is due to several factors in learning. The implementation of learning, the obstacles experienced during learning, and the characteristics of students can influence these differences.

3. Obstacles / Obstacles

Obstacles faced by researchers during the implementation of learning using learning tools that have been developed along with the alternative solutions offered are presented in Table 4.11.

Table 4.11. Constraints during the Learning Process

No	Constraint	Solution
1	Students are not proficient in formulating problems with phenomena that are raised as community issues that must be solved	The teacher provides scaffolding and trains students' science process skills first.
2	Students are not proficient in linking problem solving to	The teacher must provide scaffolding so that students can understand and

No	Constraint	Solution
	phenomena with global warming material	the learning objectives can be achieved.
3	Students are less enthusiastic about reading and gathering information, either from handouts, articles or online sources	The teacher invites and guides students to read and explore information from various sources
4	When conducting experiments using PhET Simulation (LKPD 1), students had difficulty operating the software because it was the first time operating it	The teacher introduces first about PhET Simulation and teaches how to operate it.
5	Short and solid time allocation	Teachers must be able to manage learning time well and effectively and be able to optimize important activities.

C. Results of the Effectiveness of Learning Tools

The effectiveness of the learning tools that have been developed are based on three aspects, namely scientific literacy skills and problem solving, as well as students' responses after participating in learning using the learning tools that have been developed. Scores of students' scientific literacy and problem solving skills were obtained from the pre-test and post-test. The assessment results from the pre and post-test were analyzed by the N-gain score to find out whether there was an increase in scientific literacy and problem solving of students from the developed learning tools. The feasibility of the scientific literacy questions and problem solving developed is known through validity and reliability tests that have been carried out during limited trials. In detail, these sections are described as follows:

1. Science Literacy Skills (KLS)

Before analyzing students' scientific literacy skills related to global warming material after the learning process uses the learning tools that have been developed, the researcher has conducted an empirical analysis of the items that are intended to be used as evaluation sheets when implementing learning. The aim is to determine the validity, reliability, level of difficulty, and the differentiability of the questions.

The test subjects were given to 15 students who had received lessons on global warming. The feasibility of the developed scientific literacy questions is identified through the analysis of the items presented in Appendix 4.3.

The results of students' scientific literacy skills are known through the pre-test and post-test. Pre-test questions were given to students before being given treatment with the aim of knowing students' initial abilities. While the post-test questions were given after the treatment with the aim of knowing the effect of the treatment on students' scientific literacy skills. The scientific literacy questions consist of 15 questions with five forms of questions, namely 1) multiple choice; 2) complex multiple choice; 3) true false; 4) short filling; and 5) matchmaking. The results of students' scientific literacy tests are presented in Appendix 4.4. While the distribution of data based on the Descriptive Statistics Test is presented in Table 4.12.

Table 4.12. Variable Descriptive Scores of Students' Science Literacy Test

Descriptive Statistics					
	N	Minimum	Maximum	Means	std. Deviation
Class A pretest	32	24.00	72.00	45.2500	12.36280
Class A post-test	32	75.00	100.00	86.8438	7.32257
Class B pretest	35	17.00	53.00	39.0571	9.57000
Class B Post-test	35	72.00	95.00	82.8571	5.73505
Class C pretest	36	25.00	59.00	40.6389	9.94313
Class C post-test	36	70.00	96.00	84.5833	7.56448
Valid N (listwise)	32				

Based on the results of the descriptive test in Table 4.12, it can be described that there are three classes used in the study, where the three classes have different data distributions. In class A with 32 students, the average pre-test score was 45.25 with a standard deviation of 12.36 and the average post-test score was 86.84 with a standard deviation of 7.32. Class B with 35 students who took the scientific literacy skills test had an average pre-test score of 39.06 with a standard deviation of 9.57 and an average post-test score of 82.86 with a standard deviation of 5.73. Whereas in class C the number of students, namely 36 students, had an average pre-test score of 40.64 with a standard deviation of 9.94 and an average post-test score of 84.58 with a standard deviation of 7.56.

After describing the variable values of students, then it is necessary to test assumptions or prerequisites before analyzing the data. Prerequisite test as a basic concept to determine which test statistics are then used, whether using parametric or non-parametric tests. Prerequisite test, namely the normality test. The normality test is used to determine the distribution of research data, whether it is normally distributed or not. While the homogeneity test is a prerequisite for the ANOVA test, which is used to determine statistical data groups, whether the sample data groups taken come from populations that have the same variance or not. The normality test is presented in Table 4.13 and the homogeneity test is presented in Table 4.14.

Table 4.13. Normality Test Results

Tests of Normality				
	Class	Kolmogorov-Smirnova		
		Statistics	df	Sig.
Results	Class A pretest	.131	32	.176
	Class A post-test	.117	32	.200*
	Class B pretest	.137	35	093
	Class B Post-test	.137	35	096
	Class C pretest	.137	36	087
	Class C post-test	.139	36	075
*. This is a lower bound of the true significance.				
a. Lilliefors Significance Correction				

Table 4.14. Homogeneity Test Results

Test of Homogeneity of Variances					
		Levene Statistics	df1	df2	Sig.
N-gain KLS	Based on Means	4,564	2	100	013
	Based on Median	1.136	2	100	.325
	Based on Median and with adjusted df	1.136	2	31,003	.334
	Based on trimmed mean	1.135	2	100	.326

Based on Tables 4.13 and 4.14, the data can be analyzed as follows:

a) The normality test results used the Kolmogorov-Smirnov because there were more than 30 samples. It is known that grades A, B, and C on the pre-test values were 0.176, 0.093, and 0.087 respectively and the post-test were 0.200, 0.096, and 0.075. So that the pre-test and post-test data for classes A, B, and C show a significant value above 5% (> 0.05), meaning that all data is normally distributed.

b) The homogeneity test using Levene Statistics on the N-gain of students' scientific literacy skills in the three classes shows a Sig. based on the mean of 0.013 (<0.05). So it can be said that there are sample data that come from populations with unequal or non-homogeneous variances. That is, the assumption of homogeneity is not met

Since the assumptions of normality of the pre-test and post-test data for Class A, B and C are met, then carry out a comparative hypothesis test or comparative test to find out whether there is a difference in the average of two paired or related samples, namely the pre-test and post-test. The test was carried out using parametric statistical testing, namely the paired samples test. Table 4.15 shows the results of the paired-samples test in Class A, B and C.

Table 4.15. Table of Paired-Sample T-test Scientific Literacy

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Means	std. Deviation	std. Error Means	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Class A Pretest - Class A Post-test	-41.59375	8.97257	1.58614	-44.82871	-38.35879	-26,223	31	.000
Pair 2	Class B Pretest - Class B Post-test	-43.80000	7.38361	1.24806	-46.33636	-41.26364	-35,095	34	.000
Pair 3	Class C Pretest - Class C Post-test	-43.94444	7.35214	1.22536	-46.43205	-41.45684	-35,863	35	.000

Based on Table 4.15, the data can be analyzed that the results of the paired samples test in class A, B, and C show the value of Sig. (2-tailed) namely 0.000, meaning less than 5% (< 0.05). So, it can be said that there is a significant difference (meaning) between the pre-test and post-test scores in the three classes. This shows that the implementation of learning with learning tools that have been developed can increase the post-test scores of class A and B students (H0 is rejected and Ha is accepted).

Furthermore, to determine the consistency of the pre-test and post-test values of the three classes with normal data but there are samples that are not homogeneous (Table 4.14), a non-parametric statistical test is performed using the Kruskal-Wallis test where this test is an alternative to the One test. Way ANOVA which aims to see the significance of differences in group variables. The One Way ANOVA test cannot be carried out because the homogeneity assumption test is not fulfilled, it can be seen that the data is not homogeneous (Table 4.14). The results of the Kruskal-Wallis non-parametric statistical test are presented in Table 4.16.

Table 4.16. Non-parametric Kruskal-Wallis test

Test Statisticsa, b	
	N-gain KLS
Kruskal-Wallis H	5,381
df	2
asymp. Sig.	068
a. Kruskal Wallis test	
b. Grouping Variables: Class	

Based on Table 4.186 it is known that the value of Sig. of 0.068 or above 5% (> 0.05). So it can be said that there is no significant difference in the N-gain value from the pre-test and post-test in class A, class B, and class C (H0 is accepted). Thus, it can also be said that the increase in scientific literacy of the three classes has a relatively the same increase.

After carrying out comparative tests on pre-test and post-test scores, the increase in students' scientific literacy tests can be calculated using the average normalized gain. An increase or gain score is a method to determine the effectiveness of a treatment on learning outcomes. Recapitulation of pre-test and post-test scores, as well as the gain (gain) of students' scientific literacy skills in the three classes is presented in Appendix 4.5. Figure 4.10 shows the frequency diagram of the N-gain category between the scores of students from the three classes.

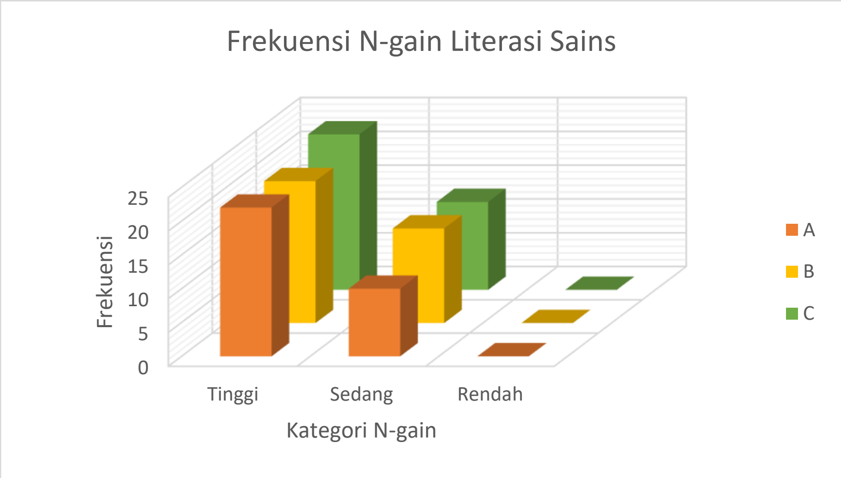


Figure 4.10. Scientific Literacy N-gain Frequency Diagram

In Figure 4.10, it can be seen that class A with a total of 32 experienced an increase in scientific literacy (N-gain) in the high category, namely 22 students, and the rest were in the medium category. A total of 21 students have N-gain in the high category and the rest are in the moderate category in class B, with a total of 35 students. In class C, 23 students experienced an increase in the high category from a total of 36 students and the rest were in the moderate category. So that the three classes have N-gain in the high and medium categories, no class has a low increase. A recapitulation of the average N-gain of students' scientific literacy skills as a whole is presented in Table 4.17.

Table 4.17. Recapitalization of Mean N-gain Science Literacy Skills

No	Class	Number of Students	Average N-gain	Category
1	A	32	0.77	High
2	B	35	0.72	High
3	C	36	0.75	High
Average N-gain of the Three Classes			**0.75**	**High**

Based on Table 4.17, it can be seen that the average N-gain score of the three classes is in the high category. The N-gain scores in each class from highest to lowest respectively are class A (0.77), class C (0.75), and class B (0.72). Overall, of the three classes, the mean N-gain score for students' scientific literacy skills was 0.75 in the High category. So, it can be said that the TPACK integrated Problem-

Based Learning learning tool is effective for improving students' scientific literacy skills.

Mastery of students' scientific literacy skills was also analyzed for each indicator. Indicators of scientific literacy skills include: (1) Explaining phenomena scientifically; (2) Evaluating and compiling scientific investigations; and (3) Interpreting data and scientific evidence. A recapitulation of the average student answers and improvement in each indicator of scientific literacy skills is presented in Appendix 4.5. Figure 4.11 presents the increase (gain) for each indicator of the scientific literacy skills of students in the three classes.

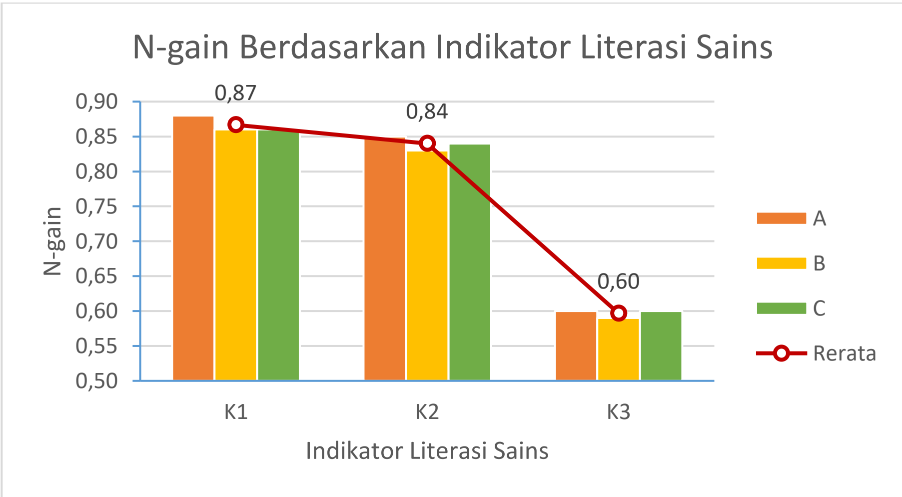


Figure 4.11. N-gain diagram for each indicator of scientific literacy

Based on Figure 4.11, it is known that the increase based on the scientific literacy indicator K1 (explaining scientific phenomena) of the three classes has an increase in the high category with the highest increase in class A, which is 0.88, followed by classes B and C with the same increase of 0. ,86. In the K2 indicator (evaluating and compiling scientific investigations) the increase is in the high category with the highest to lowest score sequence, namely class A (0.85), C (0.84), and B (0.83). The three classes on the K3 indicator (Interpreting data and scientific evidence) experienced an increase in the medium category, namely class A (0.60), class B (0.59), and class C (0.60). The increase in the K3 scientific literacy indicator has the lowest score of the three classes. This is caused by several factors, namely first, on the K3 scientific literacy indicator students are required to be able to interpret data and evidence scientifically including analyzing and evaluating experimental data, opinions in various data, and drawing conclusions. Second, the proportion of questions in K3 is more than the other scientific literacy skills, namely 7 questions, while K1 (5 questions) and K2 (3 questions). Overall it can be concluded that the increase based on indicators of scientific literacy is in the high and medium categories. the proportion of questions on K3 is more than the other scientific literacy skills, namely 7 questions, while K1 (5 questions) and K2 (3 questions). Overall it can be concluded that the increase based on indicators of scientific literacy is in the high and medium categories. the proportion of questions on K3 is more than the other scientific literacy skills, namely 7 questions, while K1 (5 questions) and K2 (3 questions). Overall it can be concluded that the increase based on indicators of scientific literacy is in the high and medium categories.

The scientific literacy questions consist of 15 questions with five forms of questions, namely multiple choice (PG), complex multiple choice (PGK), true false (BS), short answer (IS), and matching (M). Detailed details regarding the questions and their forms as well as the skills indicators measured are presented in Table 4.18. A recapitulation of improvements based on the items and the form of the questions is presented in Appendix 4.5. Figure 4.12 is a diagram of the increase or N-gain of students' scientific literacy based on the item questions. Meanwhile, the students' N-gain based on the form of the questions is presented in Figure 4.13.

Table 4.18. Forms of Science Literacy Problems

Science Literacy Indicator	**Question Number**	**Question Form**
Explaining scientific phenomena (K1)	1,2,3,7,8	True False, Matchmaking, Short Fill in, Complex Multiple Choice
Evaluating and compiling scientific investigations (K2)	4,5,6	Complex multiple choice, multiple choice, short field and matchmaking
Interpreting K3 scientific data and evidence)	9,10,11,12,13 ,14,15	True False, Complex Multiple Choice, Matchmaking,

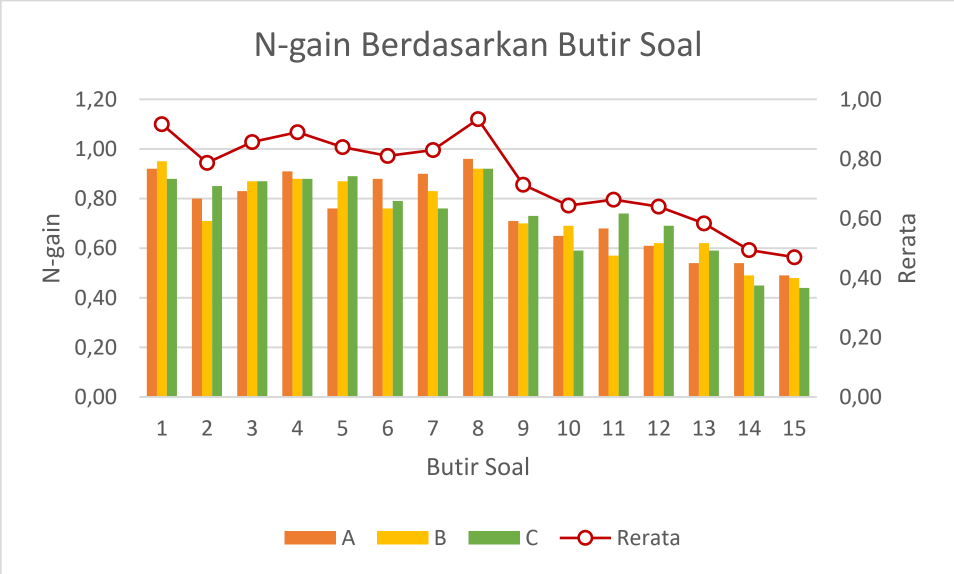


Figure 4.12. N-gain Diagram for each Item on Scientific Literacy

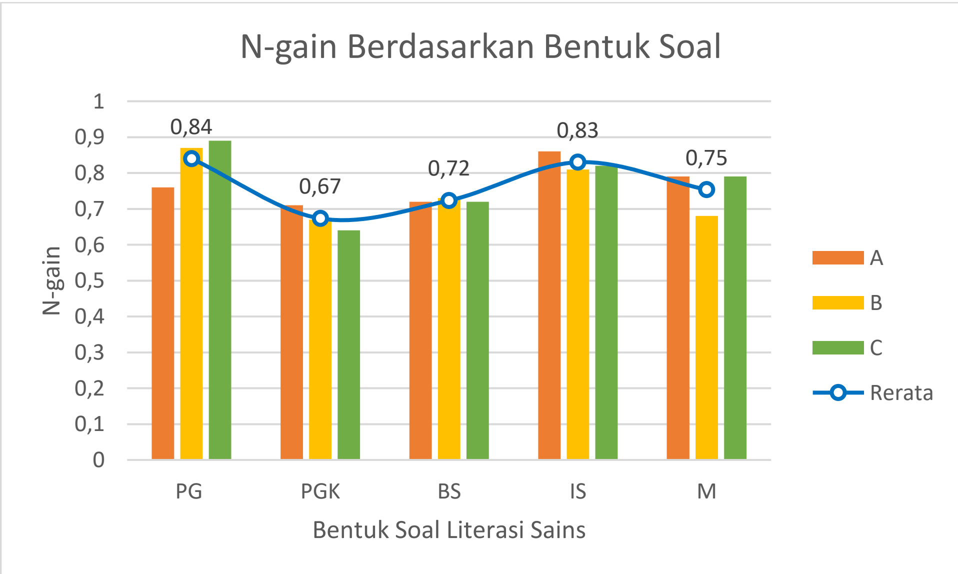


Figure 4.13. N-gain Diagram for Each Form of Science Literacy Problem

The increase (N-gain) in scientific literacy for each class based on the items presented in Figure 4.12 shows that the top 3 items that have the highest N-gain scores sequentially are item number 8 (0.93), item number 1 (0). .92), and question number 4 (0.89). Meanwhile, the 3 items with the lowest increasing score of the 15 questions given were in question number 15 (0.47), question number 14 (0.49), and question number 13 (0.58). The N-gain category of scientific literacy based on the items is in the medium and high categories. The N-gain is in the medium category, namely in questions number 10, 11, 12, 13, 14, and 15. Items with N-gain are in the high category, namely in question numbers 8, 1, 4, 3, 5, 7, 6 , 2, and 9.

In Figure 4.13, is the N-gain of scientific literacy for each class based on the form of the questions. The form of scientific literacy questions that had a moderate increase was in the form of complex multiple choice questions (PGK). While the forms of questions that have an increase in the high category are in the form of multiple choice questions (PG), short entries (IS), matchmaking (M), and major errors (BS). The N-gain increase score was based on the form of scientific literacy questions from highest to lowest sequentially, namely IS (0.83), PG (0.84), M (0.75), BS (0.72), and PGK (0.67).

Analysis of the percentage difficulty of the scientific literacy test items based on the items and the form of the questions from the increase data during the pre-test and post-test is presented in Figure 4.14.

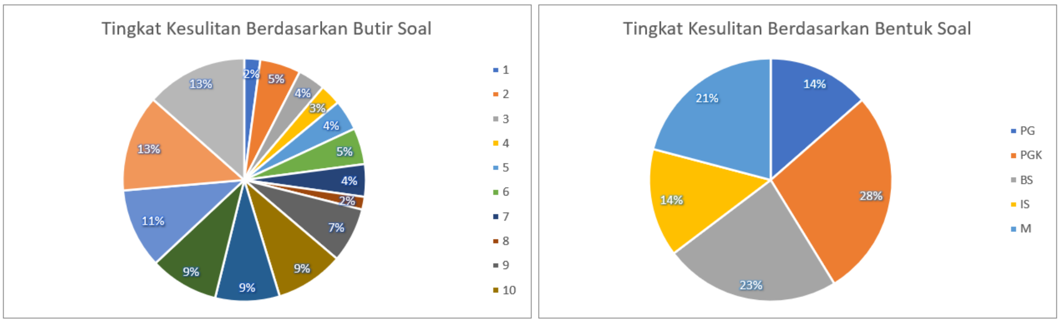


Figure 4.14. Percentage of Difficulty of the Science Literacy Test Based on the Question Items and the Form of the Question

Based on Figure 4.14, it can be seen that the difficulty of the scientific literacy test is based on the items that have the highest to the lowest difficulty percentage of the 15 questions sequentially, namely question numbers 15 (13%), 14 (13%), 13 (11%), 11 (9%)), 12 (9%), 10 (9%), 9 (7%), 2 (5%), 6 (5%), 7 (4%), 5 (4%), 3 (4%), 4 (3%), 1 (2%), and 8 (2%). While the level of difficulty is based on 5 forms of questions from the highest to the lowest percentage of difficulty, namely the form of complex multiple choice questions (28%), true false (23%), matching (21%), short answer (14%) and multiple choice (14%) .

In assessing the level of success or completeness of students' learning towards the learning process by applying the learning tools developed, the assessment is guided by the KKM score which has been determined with a value limit of 75. A recapitulation of the results of students' learning completeness is presented in Appendix 4.5. Figure 4.15 presents the results of students' learning completeness and N-gain scientific literacy of the three classes.

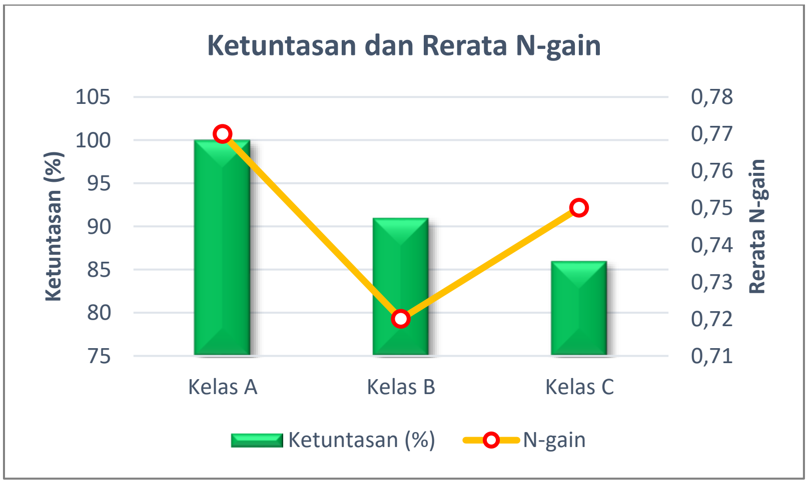


Figure 4.15. Scientific Literacy Completeness and N-gain Diagram

Based on Figure 4.15, it can be analyzed that completeness is not always proportional to the increase in students' scientific literacy. In class A, students' mastery of scientific literacy is 100% and the average N-gain is 0.77. Study completeness in class C is 91% with an average N-gain increase of 0.72. Class C has an average N-gain score that is greater than class B, but students' learning completeness is 86% or less than class B.

2. **Problem Solving Skills (KPM)**

The results of students' problem solving skills are also known through the pre-test and post-test. The problem-solving test questions consist of 5 description questions or essays, where each question requires students to be able to carry out the stages of problem-solving. Item analysis is presented in Appendix 4.6. Problem solving indicators that are measured in each question are: (1) Understand the problem; (2) Make a plan (devise a plan); (3) Carry out the plan (carry out the plan); (4) Looking back (looking back). The results of the pre-test and post-test of student problem solving are presented in Appendix 4.7 and a statistical description regarding the value of student problem solving results is presented in Table 4.19.

Table 4.19. Variable Descriptive Student Problem Solving Test Scores

Descriptive Statistics					
	N	Minimum	Maximum	Means	std. Deviation
Class A pretest	32	18.00	45.00	30.0313	7.65584
Class A post-test	32	73.00	89.00	80,0000	4.80591
Class B pretest	35	13.00	44.00	28.6286	7.58515
Class B Post-test	35	66.00	89.00	77.7143	5.89901
Class C pretest	36	13.00	46.00	29.8056	8.79552
Class C post-test	36	61.00	94.00	78.5278	7.16534
Valid N (listwise)	32				

Based on the results of the descriptive test in Table 4.19, it can be described that class A with a total of 32 students has an average problem solving pre-test score of 30.03 with a standard deviation of 7.66 and a post-test mean of 80.00 with a standard deviation of 4 ,81. In class B, 35 students who took the problem-solving test had an average pre-test score of 28.63 with a standard deviation of 7.59 and a post-test mean of 77.71 with a standard deviation of 5.90. Whereas in class C there were 36 students who took the test having an average pre-test score of 29.81 with a standard deviation of 8.79 and a post-test mean of 78.53 with a standard deviation of 7.16.

After describing the class variables of students' values, a normality test was then carried out to find out the distribution of the research data, whether it was normally distributed or not. While the homogeneity test is used to determine the statistical data group, whether the sample data group taken comes from a population that has the same variance or not. The normality test is presented in Table 4.20 and the homogeneity test is presented in Table 4.21.

Table 4.20. Normality Test Results

Tests of Normality				
	Class	Kolmogorov-Smirnova		
		Statistics	df	Sig.
Results	Class A pretest	.138	32	.124
	Class A post-test	.136	32	.137
	Class B pretest	.124	35	.191
	Class B Post-test	.100	35	.200*
	Class C pretest	.112	36	.200*
	Class C post-test	.115	36	.200*
*. This is a lower bound of the true significance.				
a. Lilliefors Significance Correction				

Table 4.21. Homogeneity Test

Test of Homogeneity of Variances					
		Levene Statistics	df1	df2	Sig.
N-gain KPM	Based on Means	1,091	2	100	.340
	Based on Median	1075	2	100	.345
	Based on Median and with adjusted df	1075	2	90,740	.346
	Based on trimmed mean	1.101	2	100	.336

Based on Tables 4.20 and 4.21, it can be seen that the data distribution:

c) The results of the normality test used the Kolmogorov-Smirnov class A, B, and C at the pre-test values respectively 0.124, 0.191, and 0.200 and the post-test were 0.137, 0.200, and 0.200. So that the pre-test and post-test data from the three classes are normally distributed because they show the Sig value. >0.05.

d) The homogeneity test using Levene Statistics on the N-gain problem solving skills of students in the three classes shows a Sig. based on a mean of 0.340, meaning greater than 5% (> 0.05). So that it can be said that all research sample data come from populations with the same or homogeneous variance (H0 is accepted).

After the pre-requisite tests were met and the data were normally distributed and homogeneous, then parametric tests were carried out, namely the paired samples test and ANOVA. The paired samples test aims to see if there is a difference between the two mean values of the pre-test and post-test or paired samples. The ANOVA test was carried out aiming to see the significance of the difference in the mean of the three class samples. The results of the parametric paired samples test using SPSS 25 are presented in Table 4.22 and the results of the ANOVA test are presented in Table 4.23.

Table 4.22. Paired Samples Test Problem Solving Skills

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Means	std. Deviation	std. Error Means	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Class A Pretest - Class A Post-test	-49.96875	5.39106	.95301	-51.91243	-48.02507	-52,432	31	.000

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Means	std. Deviation	std. Error Means	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 2	Class B Pretest - Class B Post-test	-49.08571	5.72595	.96786	-51.05265	-47.11878	-50,716	34	.000
Pair 3	Class C Pretest - Class C Post-test	-48.72222	5.54262	.92377	-50.59757	-46.84687	-52,743	35	.000

Table 4.23. Problem Solving Skills One Way ANOVA Test

ANOVA					
N-gain KPM					
	Sum of Squares	df	MeanSquare	F	Sig.
Between Groups	011	2	006	1,250	.291
Within Groups	.450	100	.004		
Total	.461	102			

Based on Tables 4.22 and 4.23, the data distribution can be analyzed:

a) The results of the paired samples test in class A, B, and C showed a Sig (2-tailed) value of 0.000 or <0.05. So, it can be said that there is a significant (meaningful) difference between the pre-test and post-test values in the three classes (H0 is rejected and Ha is accepted). This shows that the implementation of learning with learning tools that have been developed can increase students' post-test scores

b) The results of the One Way ANOVA test on the N-gain problem solving skills of students from the three classes show the value of Sig. of 0.291, meaning greater than 5% (> 0.05). So, it can be said that the average N-gain score is the same or there is no significant difference between class A, class B and class C.

N-gain (normalized gain) is used to measure the increase in students' problem-solving skills from the results of the pre-test and post-test. Recapitulation of pre-test and post-test scores, as well as the gain (gain) of students' problem-solving skills in the three classes is presented in Appendix 4.8. Figure 4.16 shows the frequency diagram for the N-gain category of students' problem solving skills from the three classes.

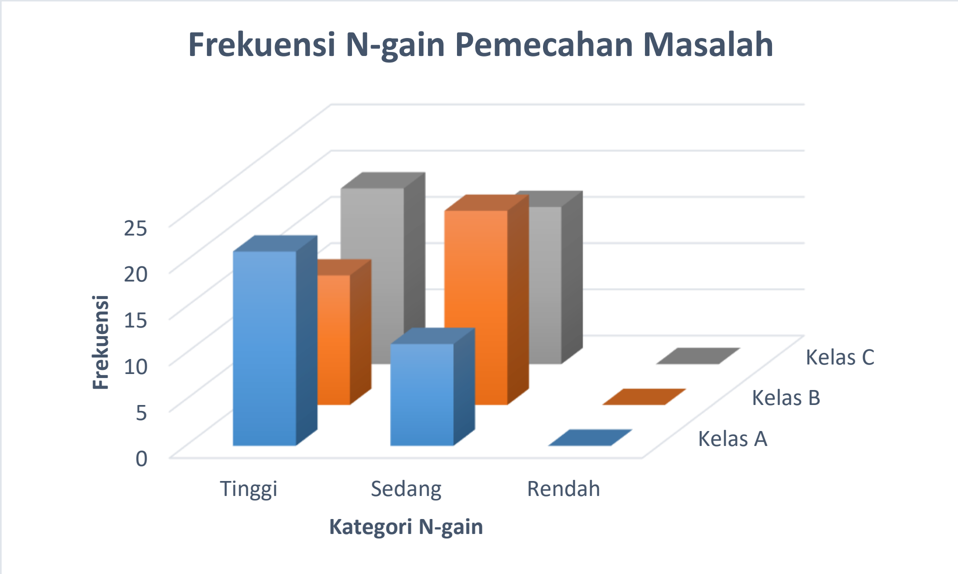


Figure 4.16. Troubleshooting N-gain Frequency Diagrams

In Figure 4.16, it is known that Class A experienced the highest increase in pre-test and post-test scores of the three classes. The high category in class A improvement is as many as 21 out of 32 students and the rest are in the moderate improvement category. The lowest increase between the pre-test and post-test scores occurred in class B, with an increase in the high category of 14 out of 35 students and the rest had a moderate improvement category. In Class C with 36 students there was an increase in the high category of 19 students and the rest were in the medium category. A recapitulation of N-gain students' scientific literacy skills as a whole is presented in Table 4.24.

Table 4.24. Recapitalization of the Average N-gain of Problem-Solving Skills

No	Class	Number of Students	Average N-gain	Category
1	A	32	0.72	High
2	B	35	0.69	Moderate
3	C	36	0.70	High
Average N-gain of the Three Classes			**0.70**	**High**

Based on Table 4.24, it can be seen that the average value of N-gain for students' problem solving skills as a whole is 0.70 in the High category. The N-gain score in the moderate category is in class B (0.69) and the N-gain score in the high category is in class A (0.72) and C (0.70). So, it can be said that the TPACK integrated Problem-Based Learning learning tool is effective for improving students' problem-solving skills.

Mastery of students' problem solving skills was also analyzed for each indicator. Indicators of problem solving skills include: (1) Understanding the problem (understand the problem); (2) Make a plan (devise a plan); (3) Carry out the plan (carry out the plan); (4) Looking back at the process and results (looking back). Figure 4.17 presents the increase (gain) for each indicator of students' problem solving skills from the three classes.

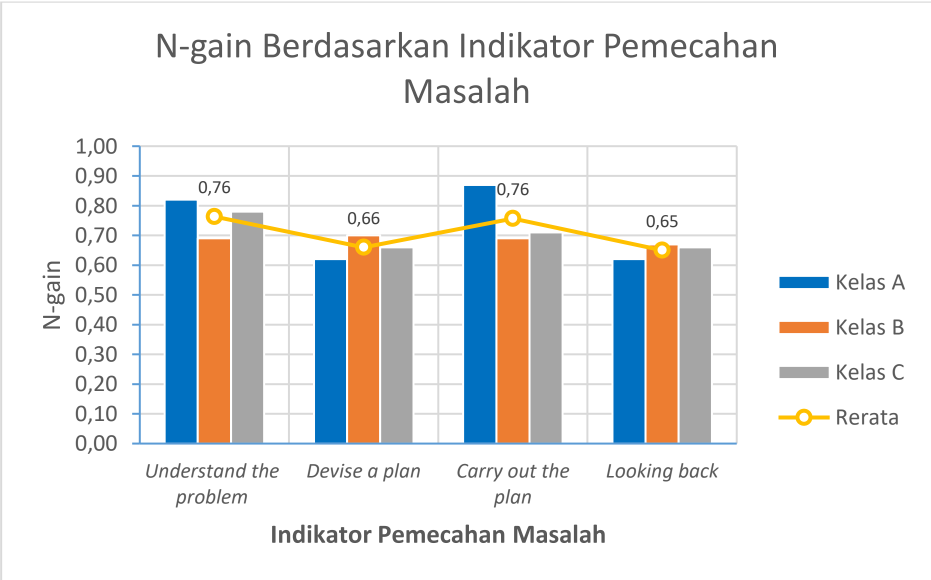


Figure 4.17. N-gain Chart for Each Problem-Solving Indicator

Based on Figure 4.17, it can be seen that the highest increasing score of problem-solving skills on the understand the problem indicator is in class A (0.82) and the lowest increasing score is in class B (0.69). The divide a plan indicator has the highest score for class B (0.70) and the lowest score for class A (0.62). The third indicator is carry out the plan, the highest increase score occurs in class A (0.88) and the lowest occurs in class B (0.69). Fourth, namely the indicator of looking back, the highest score increase occurred in class B (0.67) and the lowest in class A (0.62). So it can be concluded that, the increase is based on problem solving indicators, namely in the high and medium categories.

The form of problem solving skills test questions is in the form of essay questions (5 questions) regarding problems in global warming material. Each question that contains contextual problems requires students to be able to solve using the stages of problem solving, namely understanding the problem, making plans, implementing plans, and looking back at processes and results. The increase in students' problem solving skills can be seen from each item worked on is presented in Figure 4.18.

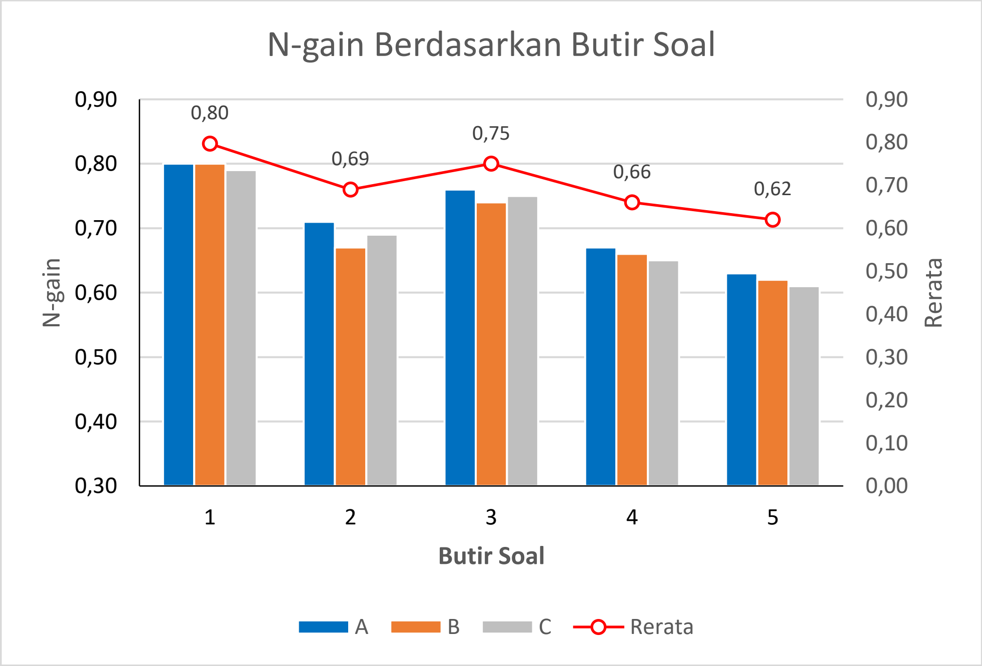


Figure 4.18. N-gain Each Point Problem Solving

Based on Figure 4.18, it can be seen that question number 1 has a high score (N-gain) in class A (0.80), B (0.80), and C (0.79). In question number 2, the class that had the highest average N-gain score was class A (0.71) in the high category, while classes B (0.67) and C (0.69) experienced an increase in the medium category. Problem number 3 of the three classes has an increase in the high category, namely class A (0.76), B (0.74), and C (0.75). In question number 4, class A (0.67), B (0.66), and C (0.65) have an increase in the medium category. The increase in the moderate category also occurred in question number 5, which occurred in class A (0.63), B (0.62), and C (0.61). The mean N-gain scores of the three classes based on the items with the high improvement category are in question number 1 (0.80) and number 3 (0.75).

The percentage of problem solving test item difficulty for students from the three classes based on the item items is presented in Figure 4.19. It can be seen that the problem solving percentages from the highest to the lowest difficulty level are question number 5 (38%), question number 4 (34%), question number 2 (31%), question number 3 (25%) and question number 1 (20.33%).

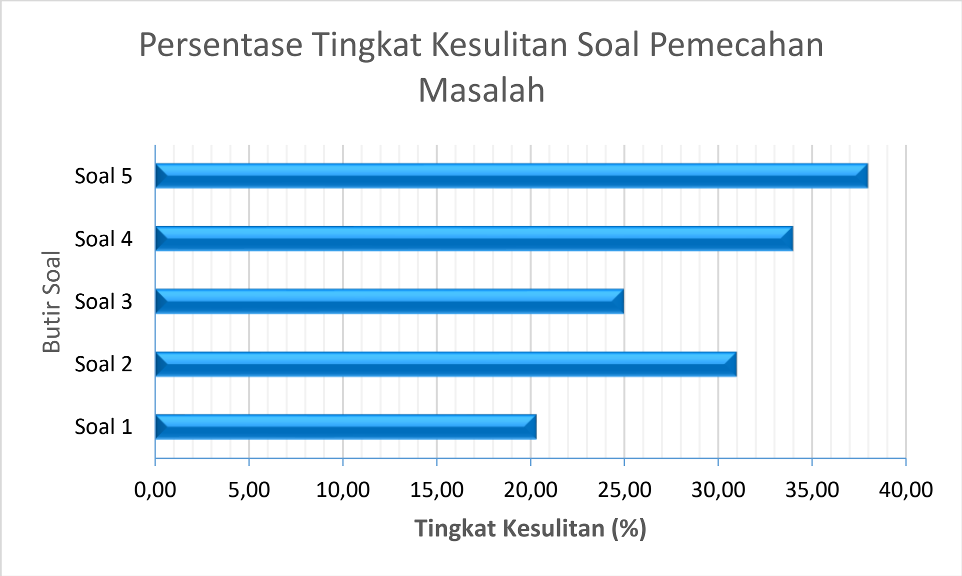


Figure 4.19. Percentage of Difficulty of Problem Solving Test

The level of success or completeness of students on the learning process that has been carried out with the learning tools developed, seen from the value of students on problem solving tests which are more than 75 (complete). A complete recapitulation of student learning completeness on problem solving skills is presented in Appendix 4.8. Table 4.25 displays the percentage of students' completeness.

Table 4.25. Percentage of Completeness of Students

Class	Completeness Percentage (%)		N-gain	Category
	Pre-test	Post-test		
A	0	84	0.71	High
B	0	71	0.69	Moderate
C	0	75	0.70	High
Average	**0**	**76**	**0.70**	**High**

Based on Table 4.25, it is known that the percentage of post-test completeness of Class A students with a total of 32 students is 84%, meaning that 27 students scored above KKM 75 (complete) and 5 students did not complete. In class B with a total of 35 students, the percentage of completeness was 71%, meaning that 25 students completed and 10 students did not complete. In class C with a total of 36 students, the percentage of completeness was 75%, meaning that 27 students completed and 9 students did not complete. Students who are not complete do not mean they do not experience an increase in problem solving skills. However, students who did not complete or scored less than KKM 75 still experienced an increase in problem solving skills, namely in the medium and high categories.

3. Student Response

To find out student responses related to learning using learning tools that have been developed, a student response questionnaire is used to assess the learning that has been done. The results of the recapitulation of student response assessment scores are presented in Appendix 4.9. Figure 4.20 shows the percentage of responses based on student answers (strongly agree, agree, disagree and strongly disagree) and the average percentage of responses for each class.

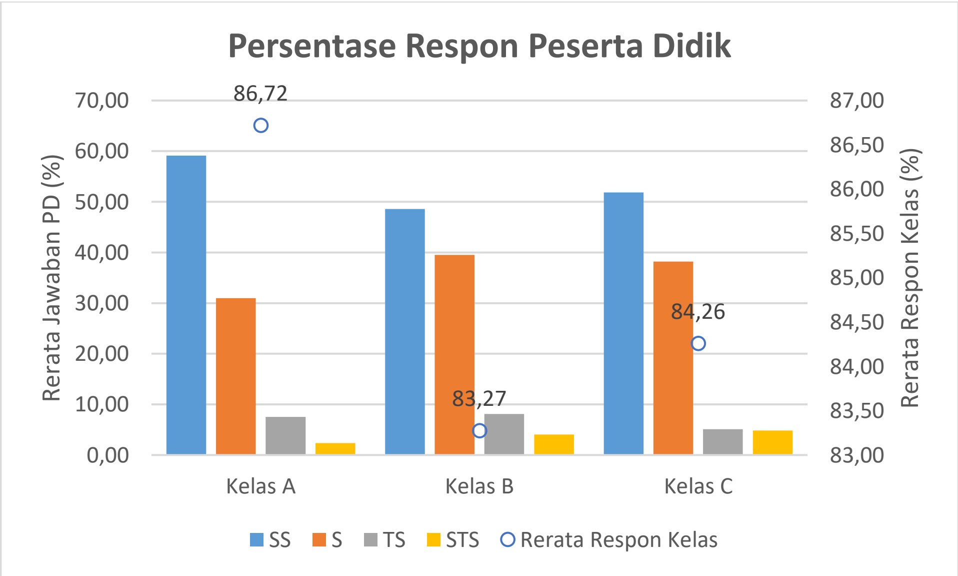


Figure 4.20. Student Response Percentage

Based on Figure 4.20, it is known that students' responses to the TPACK integrated problem-based learning tool tend to be positive. The average response of students in each class who gave the highest strongly agreed answers was in class A (59.11), then class C (51.85), and class B (48.57). The mean gave agreed answers to the three highest to lowest classes sequentially, namely class B (39.52), C (38.19), and A (30.99). Disagreeing answers from the highest average of students in each class, namely class B (8.10), then class A (7.55), and class C (5.09). While the mean answers of students from the three classes who gave answers strongly disagreed from the highest respectively, namely class C (4.86), class B (4.05), and class C (2.34). The average response of students as a whole is in the very good category.

CHAPTER V
RESEARCH DISCUSSION

This research is a research on the development of physics learning tools using the TPACK-integrated problem-based learning (PBL) model. This development research process aims to produce a feasible TPACK-integrated PBL toolkit to improve scientific literacy and problem-solving skills of MA/SMA students. There are three indicators to produce a decent product, namely validity, practicality and effectiveness(Arman et al., 2020; Pangestu & Susanti, 2022).

The validity of learning tools is in the form of syllabus validity, learning implementation plans (RPP), handouts, student worksheets (LKPD), and evaluation sheets (LE). The learning tools developed were validated by three expert/expert lecturers. The valid device was tested limited to 32 students of class X MAN 2 Lamongan, then it was tested extensively on 103 students randomly from class X MAN 2 Lamongan. The practicality of the learning tools developed includes the implementation of learning, the activities of students during the learning process, and the obstacles encountered during the implementation of the learning tools that were developed. The effectiveness of learning devices is observed from scientific literacy skills, problem solving skills, and students' responses after participating in learning.

A. The Validity of Learning Tools

1. Syllabus

Syllabus is one of the components of learning tools that is used as a reference for compiling a framework in learning for each subject study material (Kermendikbud, 2016). The principles of syllabus development include being relevant, scientific, consistent, adequate, systematic, actual, flexible, contextual and comprehensive (Kemendikbud, 2016). The function of syllabus development is to assist in maximizing and becoming a means to actualize the curriculum operationally at the educational unit level(Nuraini, 2019). The developed syllabus is based on standard content, which contains components including: 1) Subject identity; 2) School profile; 3) Core competencies; 4) Basic competence; 5)

Indicators of competency achievement; 6) Main material; 7) Learning activities; 8) Time allocation; 9) Learning resources and 10) Assessment(Permendikbud No 22, 2016). The syllabus is actually a big plan that needs to be broken down into more detailed and specific lesson plans such as lesson plans (RPP), textbooks (handouts), student worksheets (LKPD), and scientific literacy tests and problem solving. This is supported by Afifa's research(2020)that the syllabus is the foundation for teachers to achieve the competencies they want to explore.

The results of the syllabus assessment are presented in the previous chapter in Table 4.1. The results of the validator's assessment of each aspect of the syllabus presented in Table 4.1 show that the mode of syllabus validation results is in the very valid category. The percentage of agreement or the percentage of compatibility by the three validators in all aspects of the syllabus is 92.20%, meaning that the syllabus as a whole (content, presentation, and language) is declared reliable. According to Permendikbud (2016) a syllabus is declared valid if the components of the syllabus are met, namely format, identity, formulation of objectives, learning activities, learning resources, time allocation, and assessment. If the syllabus is considered valid, then the syllabus can be tested with later revisions(Yanuarni et al., 2021). The syllabus developed by the researcher has very valid criteria so that it is feasible for limited trials and wide trials.

The developed syllabus also contains learning activities that show the stages of the Problem Based Learning learning model with the TPACK approach to train students' scientific literacy and problem solving skills. Even though the results of the validity value are high, the syllabus developed cannot be said to be perfect. There are suggestions and input from the validator.The input provided by the validator regarding the improvement of syllabus development and improvement efforts made by researchers is presented in Table 4.2.After making improvements according to the suggestions from the validator, the syllabus is feasible to be implemented or tested on a limited basis and extensive trials.

2. Learning Implementation Plan (RPP)

The lesson plan (RPP) is a lesson plan that describes the material and teaching steps in detail at a specified time. RPP development refers to the syllabus as the basis for planning learning activities (Permendikbud, 2013). RPP is used to streamline the implementation of learning activities so that they are more effective. Educational units, subjects, classes or semesters, subjects, time allocations, indicators, learning objectives, learning materials, learning models and methods, learning resources, learning steps, and assessments are all included in the learning implementation plan (Kemendikbud, 2016).

The RPP developed by the researcher uses the TPACK integrated problem-based learning (PBL) model. The RPP developed aims to improve students' scientific literacy and problem solving skills. Scientific literacy skills and problem solving are skills that must be possessed by students in today's development(Hidaayatullah, 2022; Hidaayatullah et al., 2020), so that the RPP must be well prepared with each lesson presenting phenomena and problems that occur in the surrounding environment. According to the Minister of Education and Culture No. 20 of 2016, the process standard requires that every education unit teacher prepare a comprehensive and methodical lesson plan so that teaching and learning activities can take place in an interactive, inspiring and fun way, and encourage students to be active(Nurjanah et al., 2022).

The RPP in this study consisted of two meetings with 2 JP each meeting (2 x 45 minutes). The learning model used is the problem-based learning model or integrated TPACK problem-based learning. Learning by using the problem-based learning model provides students with learning experiences to practice scientific literacy skills and problem solving based on trends or issues and phenomena in everyday life that are presented in learning. Through the phases of the PBL model, students are indirectly literate in science to the trend of the global warming phenomenon and can analyze the problems that occur, so that students' learning is more meaningful.

The quality of the lesson plans developed by researchers in this study can be seen from the validation results by three expert lecturers in the previous chapter.

The validator validates aspects of the format of the content, presentation, and discussion in the RPP component. Based on the validation results, it was obtained that the category mode of all aspects assessed was very valid with an average*percentage of agreement*of 92.06%. The validator provides suggestions aimed at improving or perfecting the RPP. As for suggestions from the validator, namely learning indicators are directed to the skills being trained (scientific literacy skills and problem solving), the TPACK approach is more prominent in learning activities, and the time allocation needs to be adjusted again to the formulated learning objectives.

3. Handouts

*Handouts*is a collection or material used to support teachers in achieving competence and learning objectives. The development of teaching materials needs to comply with several rules including being able to change behavior, according to conditions, specific learning objectives according to the curriculum, containing detailed subject matter. Therefore, in developing teaching materials it is necessary to look at efficiency, effectiveness, and content balance according to the needs of students. A handout is said to be practical if it has several criteria including being unambiguous, easy to digest, and adapted to developments from year to year so that it is expected to strengthen scientific concepts.(Uki & Bire, 2021). This opinion is reinforced by a study conducted by Haryanti & Fatisa(2021)states that through quality handouts it can support students to explore material, sentence vocabulary, and improve scientific literacy skills.

*Handouts*which was developed by the researcher, which contains global warming material adapted to basic competence 3.12. This handout can also be accessed online to make it easier for students to study wherever and whenever. The handout that the researchers compiled was not just reading material but emphasized more on solving problems related to global warming. Thus, the material that will be taught by the teacher to students is included in the learning handout, which includes practice questions that are completed at the end of the lesson.

The handout validation developed shows that the mode category is very valid in all aspects including format, content, and language with a percentage of agreement of 92.86%. As for suggestions from the validator regarding the developed handouts, it is necessary to add contextual phenomena, students' sheets also need to be included, and it is necessary to add discussions regarding scientific literacy in the practice questions in the handouts. A good handout, which has accuracy from the aspect of its presentation. Aspects of the format that has a very valid category mode include aspects of the presentation of the learning device validation instrument components. In addition, handouts must be student-centered, communicative, and follow the correct Indonesian grammar rules(Rifandi et al., 2019; Rusli et al., 2021).

4. Student Worksheets (LKPD)

Student worksheets developed by researchers are used as a guide for students in discovering the physics concept of integrated global warming TPACK material using the problem-based learning model. The results of the developed LKPD validation obtained the average mode of all aspects which include content, constructs, and language, namely very valid with an average*percentage of agreement*of 92.64%. The results of LKPD validation by the validator can be seen in Table 4.7. Suggestions for improvement from the validator on the developed LKPD are that it is necessary to align the objectives of the LKPD with the objectives set in the RPP, it is necessary to emphasize the issues raised in the LKPD, and it is necessary to discuss scientific literacy of the problems in the LKPD.

The LKPD developed by the researcher contains the stages of the TPACK integrated problem-based learning model, so that the LKPD can be accessed and can be done online through liveworksheets. Researchers compiled two LKPD for two meetings. The first LKPD is about The Green House Effect by conducting an experiment using PhET Simulation. In LKPD 1, students are presented with problems regarding the phenomenon of the greenhouse effect in everyday life and students are required to be able to understand the concept of the greenhouse effect and be scientifically literate about the phenomena/impacts that are happening at this time. The second LKPD is about Eco Friendly Houses, where students make a work in the form of an environmenHighy friendly house design that can contribute to reducing greenhouse gas emissions which result in global warming.

The researcher presents LKPD which facilitates students as a group in identifying problems, formulating problems, making hypotheses, testing hypotheses through experimental activities, analyzing experimental data, making conclusions, and presenting the work. LKPD grammar has been adapted to the communicative and Indonesian national language. The sentences used are in accordance with the level of thinking of students, do not contain double meanings, and provide clear instructions. This can be seen from the fact that most groups of students are able to work on the LKPD optimally during learning. This is in line with what Astuti said(2021)which states that students may be able to work on LKPD more efficiently if the instructions or language used in their preparation are clear.

5. Evaluation Sheet (LE)

Evaluation sheets are used to measure student skills, where the skills trained are scientific literacy skills and student problem solving skills. The evaluation sheet or scientific literacy test sheet consists of 15 questions regarding global warming with five forms of questions, namely multiple choice, complex multiple choice, true/false, short answer, and matchmaking. The indicators of scientific literacy that are measured are explaining scientific phenomena (K1), evaluating and compiling scientific investigations (K2), and interpreting data and scientific evidence (K3). As for the problem solving test sheet, which consists of 5 questions in the form of a description, where in each question students are required to be able to solve problems with problem solving stages. The measured problem solving indicators are understanding the problem,

The validation results of the evaluation sheet developed obtained the category mode from all aspects, namely very valid with a percentage of agreement of 90.91%, meaning that the LE validation sheet as a whole (content, presentation, and language) was also declared reliable. So that LE is relevant to use in designing learning and can be accounted for scientifically. As for suggestions from the validator, namely the need to separate tests to measure scientific literacy and student problem solving, improvements to the layout, consistency of indicators, and the need to add sources to images. After the test sheet was declared theoretically valid and received suggestions for improvement from the validator, the researcher improved the test sheet according to input from the three validators. Furthermore, researchers conducted trials to obtain the validity of the test sheet empirically.

This test serves as a pre-test to determine students' initial scientific literacy and problem-solving skills and a post-test, namely to determine scientific literacy and problem-solving skills after students take part in learning using the developed learning tools. The results of students' scientific literacy and problem solving skills are handled like learning outcomes (complete and incomplete), then look at the N Gain obtained from the pre-test and post-test. The researcher arranges a question grid with indicators before compiling the test sheet so that the question instrument must be made in accordance with the indicators and learning objectives to be addressed. The preparation of questions must cover the subject matter being taught by taking into account the urgency, relevance, continuity and context(Alika et al., 2018; Yasiro et al., 2021).

B. **The Practicality of Learning Tools**

Learning devices are said to be practical if they can be used easily by lecturers/teachers and students/students according to the wishes of the developer(Mahlianurrahman, 2020; Silalahi et al., 2021). In this study, the practicality of learning tools that have been developed is based on the implementation of learning, the activities of students during the learning process, and the constraints/obstacles encountered during the learning process, and. The details of the discussion of the practicality of learning devices are as follows.

1. Implementation of Learning

The implementation of learning can be seen through the observation sheet of the implementation of learning which is filled in by two observers during two meetings. Recapitulation of the results of observations of the implementation of learning has been presented in Appendix 4.1. Implementation of learning is analyzed based on three reviews. First, it is reviewed based on the implementation at each meeting. Second, it is reviewed based on the learning activities as a whole. Third, it is reviewed based on the stages or phases of the problem-based learning

(PBL) model in the core learning activities. In each phase of PBL in learning to train students' scientific literacy skills (KLS) and problem solving skills (KPM).

First, when viewed from the overall implementation at each meeting presented in Figure 4.1, it can be seen that the average learning implementation in the three classes at the first and second meetings has a percentage in the very good category. This means that the teacher in carrying out the TPACK integrated PBL model learning is in accordance with the learning implementation plan (RPP) that was developed. RPP was developed from a syllabus that is useful for facilitating teachers in delivering material, setting targets and objectives, developing learning activities, elaborating types of assessment, and determining learning resources(Build et al., 2019).

Second, an overview of the percentage of implementation of learning as a whole, namely preliminary, core, closing activities, time processing, and class atmosphere is presented in Figure 4.2 (class A), Figure 4.3 (class B), and Figure 4.4 (class C). It is known that, at the first and second meetings of the three classes, the average performance was in the good and very good categories. Very good category with a very high percentage of implementation of the three classes, namely in the preliminary activities and class atmosphere. Meanwhile, the implementation which has a small percentage with a good category is time processing.

In the preliminary activities, the teacher conveys according to the developed lesson plan, namely giving apperception and motivating students by presenting phenomena and trends regarding recent global warming. In the preliminary activities the TPACK components that emerged were CK, PK, and PCK. Preliminary activities in learning are very important to do, because without interest from students in learning, learning cannot take place properly.(Arafah et al., 2020; Dewi et al., 2019). In addition, the teacher also invites students to think about the phenomena that are broadcast and invites students to identify existing problems. Problem identification aims to find out exactly what problems occur, what strategies and solutions are appropriate to overcome these problems(Hendriana et al., 2018). To achieve the expected learning objectives, a teacher must try to monitor and maintain students' attention during the learning process.(Putra Wijaya et al., 2021).

Processing time of the three classes gets the smallest percentage of all aspects. This is because based on the RPP all tasks such as LKPD should be completed at each meeting. But due to time constraints, it was made as a homework assignment and continued at the next meeting. The problem of time is also one of the shortcomings of the problem-based learning model, where successful learning through problem-based learning requires quite a lot of time for preparation and implementation.(Efriana, 2021; Setyo et al., 2020)

Third, an overview of the implementation of each phase of learning is presented in Figure 4.5. In the core activities, the learning model used by the teacher is in accordance with the tools developed, namely using the problem-based learning model. It is known that, in general, the average percentage of implementation in each learning phase belongs to the very good category. The succession percentage values from highest to lowest were Phase II (88.54), Phase V (83.33), Phase IV (83.61), Phase I and III (81.94). Exposure to the activities of each phase in learning using the problem-based learning model is as follows.

Phase I, namely the orientation of students on the problem of getting the percentage of implementation in the very good category from the three classes. The teacher succeeded in conveying learning objectives, motivating students to be actively involved in learning activities, and presenting and identifying problems in everyday life regarding global warming. The TPACK components in phase I that emerged were TK, TPK, and PCK while the skills trained were understanding problems (KPM indicator 1) and explaining phenomena scientifically (KLS indicator 1). This is in line with Ausubel's meaningful learning theory which says that learning will be more meaningful when it is associated with real-world situations(Agra et al., 2019). In addition, teachers must also be able to apply scaffolding to students so that they can stimulate students' thinking and be active in learning. This is in line with Vygotsky's theory which states that students can more easily master the material if the teacher provides them with scaffolding.(Devi, 2019).

Phase II is organizing students to learn. The teacher in this phase is helping students define, organize tasks related to the problem, and determine the type of information needed to reach a solution. Students are asked to open the handouts that have been distributed beforehand and form groups to work in their groups to complete the LKPD on The Greenhouse Effect (first meeting) and Eco Friendly House (second meeting). In phase II the TPACK components that emerged were TK and TCK. Studying in groups to solve the problems presented is applied to this phase, with groups of social souls students will be trained and can help participants increase their understanding(Astuti, 2021). Plus, it can help build confidence, and can give each other more ideas(Ma et al., 2018).

Phase III is guiding the research group. In this phase the teacher guides students to reformulate the problem and propose hypotheses based on the problems at the beginning of learning by collecting information from various sources such as books, articles or online sources. Furthermore, students carry out experiments in accordance with the LKPD that has been distributed to find explanations and problem solving. TPACK components related to phase III are TCK and TPACK. The scientific literacy skills trained in this activity are evaluating and designing scientific investigations (KLS indicator 2) and the problem solving skills trained are planning completion and carrying out plans (KPM indicators 2 and 3).(Febrianti & Purwaningrum, 2021). Brunner in learning theory also shows that students' discovery-based learning knowledge is durable and easy to remember, that concepts and principles are easier to apply in new situations, and can train cognitive skills to find and solve problems independently.(Mcleod, 2018).

Phase IV is developing and presenting the work. In this phase students are asked to analyze problems in LKPD in groups and guide students in developing their knowledge by looking for theories or scientific articles that support and strengthen their findings. After that, the students and their groups presented their work in the form of a report on the greenhouse effect (first meeting) and eco-friendly house design models (second meeting). Learning to express opinions or find their own answers to a question can develop curiosity and encourage students to develop their own abilities.(Gustia et al., 2019; Lesilolo, 2019). The integrated

TPACK components in this phase are CK, TPK, and TPACK. Scientific literacy skills on indicator 3 or K3, namely interpreting / interpreting data and evidence scientifically, are trained in this phase.

Phase V is the final phase, namely analyzing and evaluating the problem solving process. The teacher evaluates the problem-solving process by reflecting on the results of the investigation and the processes used in the investigation. Students with the guidance of the teacher construct their thoughts and activities during the learning that has been carried out by conveying the important points obtained and concluding the lesson. The integrated TPACK components in this phase are CK, PCK, and TPACK. Problem solving skills in the fourth indicator that are trained in this phase are checking back and evaluating the processes and results that have been done. At the end of the study, students are guided by the teacher to associate problems at the beginning of learning with the results obtained and conclude learning as a whole. If students can conclude learning, then they have constructed the results obtained with the problems presented at the beginning of learning(Sukasni & Efendy, 2017).

Based on the description above, it can be concluded that the implementation of learning in general belongs to the "very good" category. These results can be said that the researcher succeeded in implementing the TPACK integrated problem-based learning model phase. Therefore, this learning is expected to be able to improve students' scientific literacy and problem solving skills. Thus, the learning tools that have been developed are declared practical according to the practicality criteria by Nieveen(2013), which states that the practicality of the instructional device is the intervention expected to be used in the setting for which it has been designed and developed. In this case, the learning tools that have been developed can be used by teachers, so they are able to train students' scientific literacy and problem solving skills in physics lessons.

2. Student Activity

The practicality of learning tools developed based on student activities will be discussed in two reviews. First, in terms of the activities of students based on the observed aspects and secondly, based on the activities of students in each class. In this case, there are 10 student activities observed, namely:1)Hearing and observing the motivation, apperception, and goals conveyed by the teacher; 2) Understand the problem and be able to explain phenomena scientifically; 3) Reading handouts or looking for information on teaching materials according to the content; 4) Planning settlements and scientific investigations; 5) Implement plans and evaluate; 6) Working on LKPD and designing works; 7) Working together with groups; 8) Interpret or interpret data and evidence scientifically; 9) Check and evaluate the work; and 10) Asking or responding to questions.

First, the activities of students in learning during the two meetings are presented in Figure 4.6 and Figure 4.7 and based on the observed aspects are presented in Figure 4.8. The average percentage of student activity from the three classes at the first meeting was in the good category. Class A has a very good activity category at the first meeting, while class B and C have a good category. At the second meeting there was an increase in the percentage score of student activity, that is, the average percentage of the three classes was in the very good category except for class B which was in the good category.

Based on the aspects observed, the two student activities that had the highest percentage were students working on LKPD and designing works and working with groups. This is because students in learning are very interested in working in groups on LKPD 1 (The Greenhouse Effect) through PhET Simulation and designing houses with the concept of environmenHighy friendly homes that can contribute to minimizing GHG emissions that cause global warming through LKPD 2 (Eco-Friendly House). . Learning with groups makes the learning process more fun, not boring, and there is positive communication for students(Triyanto, 2019). Learning media using PhET Simulations can stimulate students to be more active and develop abilities and can improve students' thinking skills(Haryadi & Pujiastuti, 2020). While the lowest percentage is in the aspect of understanding the problem and being able to explain phenomena scientifically. This is because students sometimes still have difficulty understanding problems in global warming material. In line with research conducted by Oktavia (2019), that global warming material includes physics material in high school which is abstract and is considered difficult because it studies processes that occur in nature whose causes cannot be directly observed.

Second, the activities of students in each class are presented in Figure 4.9. it is known that class A and C have an average percentage of student activity in the very good category while class B is in the good category. If we relate it to the implementation of learning, the percentage of learning implementation is in the very good category for the three classes, even class B has the second highest percentage of implementation. But in class B student activities are in third place. This is because the ability of students is different for each class. Factors that affect the activities or learning styles of students in the learning process are differences in students' family backgrounds, differences in student readiness, differences in levels of intelligence, and differences in students' perceptions and interests(Nurlia et al., 2017; Yulianci et al., 2021).

Based on the description above, it is known that in general students are able to follow the learning very well. This is in accordance with Piaget's developmental theory, that students are able to think abstractly and logically by using probable thinking patterns in solving problems and formulating concepts.(Nainggolan & Daeli, 2021). In accordance with John Dewey's learning theory as well, thatThe teacher as a motivator for students to be involved in problem solving projects and helps students investigate problems, guides and facilitates in finding answers(Cherlin, 2020; Thomassen & Jørgensen, 2020).Thus, through learning with the TPACK integrated problem-based learning model developed by students, they are already able to move according to the observed aspects or indicators of scientific literacy and problem-solving skills.

3. Learning Constraints

Learning constraints are an obstacle that hinders the smooth learning process. The existence of obstacles can interfere with achieving maximum learning goals. Learning problems can come from two factors, namely internal and external factors. These internal factors are factors inhibiting the smooth learning of the students themselves, while external factors are external factors or environmental conditions that become obstacles to smooth learning(Anisa & Yuliyanto, 2017; Cahyo, 2019).

Obstacles from internal factors are the first, students have difficulty working on worksheets that train scientific literacy and problem solving skills. Students are still not proficient in understanding problems and explaining phenomena scientifically. This is because, previously, many students had never conducted an experiment and worked on worksheets in such a form. This first meeting was less effective because the students did not yet know the expected answers to the questions asked in the LKPD. Teachers also spend more time introducing and explaining variables that are unknown to students. The second obstacle is that students are less enthusiastic about reading and gathering information from various sources so that they have difficulty working on the LKPD on the problem of conducting literature studies. Third, students have never operated a PhET Simulation, so that at the first meeting when working on LKPD 1 (The Greenhouse Effect) students had difficulty operating it.

The alternative solutions are (1) the teacher explains the flow of the learning process to be carried out, so that students know what to do; (2) the teacher explains how to answer each question in the LKPD; (3) explaining briefly and scaffolding students if they do not know the variables or terms in the questions in the LKPD; (4) guide participants to read and gather information from various sources for literacy and strengthen the results obtained by students during the experiment. (5) first introduce students to how to operate a PheT Simulation.

External factors are related to internet signals, so that students when working on LKPD and test sheets are constrained in answering questions. Besides that, when doing online learning at the second meeting, some students had difficulty joining the class. However, regardless of the obstacles faced, the overall learning process can run smoothly. This is also an improvement from the deficiencies in the learning process during the limited test, so that all obstacles encountered at the previous meeting are resolved properly.

C. The Effectiveness of Learning Tools

Learning devices are said to be effective if these devices can achieve the expected results(Nieveen & Folmer, 2013; Syafitri et al., 2021). In this case, the hope to be achieved is to increase literacy and problem solving skills, as well as students' responses related to these devices.

1. Science Literacy Skills

Based on the discussion of the validity of learning tools, it is known that the scientific literacy test assessment sheet is stated to be theoretically valid, namely the assessment of experts and empiricists, namely based on the results of the test questions (Appendix 4.3).The results of students' scientific literacy tests are known through the pre-test and post-test. Pre-test questions were given to students before being given treatment with the aim of knowing students' initial abilities. Post-test questions were given after the treatment with the aim of knowing the effect of the treatment on students' scientific literacy skills.

Analytical questions that connect aspects of students' knowledge with the daily phenomenon of global warming are items in this scientific literacy test. The scientific literacy test is used as an illustration of the extent to which students apply scientific knowledge in life. The form of scientific literacy questions consists of 15 questions with five varied forms of questions, namely 1) multiple choice (PG); 2) complex multiple choice (PGK); 3) true false (BS); 4) short entry (IS); and 5) matchmaking (M). While the indicators of scientific literacy that are measured are, 1) explaining scientific phenomena (K1); 2) evaluating and compiling scientific investigations (K2); and 3) interpret data and evidence scientifically (K3).

The results of students' scientific literacy tests are presented in Appendix 4.4 and the distribution of statistical data on the pre-test and post-test values of scientific literacy is presented in Table 4.12. The results obtained show that the minimum score in the pre-test is smaller than the post-test, as well as the maximum value. This shows that students' post-test scores are better than pre-test scores(Hidaayatullaah et al., 2020; Suprapto et al., 2021). Therefore, the distribution of data between the pre-test and post-test values of scientific literacy is also different.

To find out whether there is a difference between the pre-test and post-test scores, an inferential statistical test is performed. The technique used is the Paired Samples Test. Because the pre-test and post-test values fulfill the assumption test (normality test). In accordance with the results of the normality test using the Kolmogorov-Smirnov presented in table 4.14, it shows that the pre-test and post-test values in class A, B, and C have a significance value above 5% or (Sig.) > 0.05. This means that the distribution of data is normally distributed. Because the test results fulfill the assumption test, to analyze the significance of the pre-test and post-test values, parametric statistics (Paired Sample T-test) are used. The paired sample t test aims to determine whether there is a difference in the mean of the two samples (two groups of variables) that are paired or related to each other(Sugiyono, 2019; Yeager, 2022).

The results of the Paired Samples Test are presented in Table 4.15, showing that class A, B, and C show Sig. (2-tailed) ie 0.000 less than 5% (< 0.05). If the value of Sig. (2-tailed) < 0.05 then H0 is rejected and Ha is accepted(Santoso, 2018). So, it can be said that there is a significant (meaningful) difference between the pre-test and post-test scores (Ha is accepted). Thus, it can be interpreted that there is a significant difference between students' scientific literacy learning outcomes in the pre-test and post-test data from the three classes. This shows that there is an influence from the implementation of learning with learning tools that have been developed on improving learning outcomes (post-test) of class A, B, and C students.

Furthermore, to determine the consistency of the pre-test and post-test values of the three classes with normal data but there are groups or samples that are not homogeneous, a non-parametric statistical test is performed using the Kruskal-Wallis test where this test is an alternative to the One Way ANOVA test. which aims to see the significance of differences in variable groups(Yeager, 2021). The One Way ANOVA test cannot be carried out because the homogeneity assumption test is not met (Ostertagová et al., 2014), it can be seen that the data is not homogeneous (Table 4.14). The non-parametric Kruskal-Wallis test is presented in Table 4.16, which shows that the Sig. (2-tailed) namely 0.068 or > 0.05 (above 5%). That is, there is no significant difference in the N-gain scores from the pre-test and post-test in class A, class B, and class C (H0 is accepted). Thus, it can also be said that the increase in scientific literacy of the three classes has relatively the same increase.

Once it is known that there is a difference between the pre-test and post-test values, the size of the difference can be analyzed using the average normalized gain both in terms of the N-gain of each learner, based on each indicator of scientific literacy, item, and question form . Overall, the average N-gain was obtained for the three classes, namely in the high category, namely class A (0.77), class B (0.72), and class C (0.75). The N-gain score based on scientific literacy indicators is presented in Figure 4.11. Figure 4.12 presents the N-gain based on items and based on the form of the questions presented in Figure 4.13.

When viewed from the indicators of scientific literacy skills (Figure 4.11), it is known that the three classes have an increase in gain in the high category with the highest increase in class A, followed by class B, and C. On the third K2 indicator (evaluating and compiling scientific investigations) class also experienced an increase in the high category. While the increase in the moderate category occurs in the K3 indicator (interpreting data and scientific evidence). Based on these results, it shows that students still have difficulties in interpreting data and scientific evidence which include: 1) evaluating scientific opinions and facts from various literature, 2) analyzing data and drawing conclusions, 3) distinguishing scientific opinions and unscientific opinions, and 4) identify concepts, facts, theory related to science. The proportion of questions on the third indicator of literacy skills (K3) is higher than the questions on indicators K1 and K2. Therefore, this factor is one of the factors that can influence OSH to have a low score compared to the other two indicators of scientific literacy. Research by Bagasta et al.(2018)revealed that one of the factors indicating a lack of students' scientific literacy skills, especially in indicators of interpreting data and scientific evidence, is that students are still weak in critical thinking, inductive-deductive reasoning, and analyzing scientific data.

The increase in the scientific literacy N-gain score obtained by students differs from one to another. This difference is because students who are active and enthusiastic in learning and in carrying out tests have different characteristics. In addition, behavior during the learning process is lacking in providing guidance to students in working on questions. In line with previous research according to Jufrida et al.(2019), which says that there are several factors that influence students' scientific literacy, namely psychological factors (student motivation and interest in learning), family factors (educational background and parental guidance), school factors (teacher teaching methods, teaching materials or learning media, infrastructure), and other learning activities. Students' learning interest in science also affects the level of scientific literacy skills (Nurlia et al., 2017; Risa Bagasta et al., 2018).

In terms of increasing students' scientific literacy based on the items (Figure 4.12), it is known that the top 3 items that have the highest N-gain scores sequentially are item number 8, item number 1, and item number 4. Meanwhile, 3 items with scores the lowest increase of the 15 questions given was found in question number 15, question number 14, and question number 13. Overall the N-gain category of scientific literacy based on the items is in the medium and high categories. In questions number 8 and 1 are questions with K1 scientific literacy indicators, where students in the questions are required to identify and explain issues related to the effects of global warming and efforts to reduce GHG emissions. In question number 4, which includes questions with K2 indicators, where students are able to evaluate and compile scientific investigations by formulating problems regarding the Greenhouse Effect experiment. While the top 3 questions that have the lowest score increases (numbers 13, 14, 15) are questions with K3 indicators, namely students are required to be able to interpret data and empirical evidence from tables and graphs regarding increasing CO2 levels, increasing earth's temperature, and total mass melting ice. In line with Pahrudin et al. and the mass of ice that melts. In line with Pahrudin et al. and the mass of ice that melts. In line with Pahrudin et al.(2019)which explains that the low scientific literacy skills are due to the ability of students to express the contents of the given discourse and interpret data in the form of pictures, tables, diagrams, and other forms of presentation which are still weak.

The increase in scientific literacy from the review of the form of the questions presented in Appendix 4.5 and Figure 4.13 shows that, the forms of questions with the highest to the lowest percentage difficulty level respectively are complex multiple choice, true/false, matching, short entries, and multiple choice. Complex multiple choice has the highest level of difficulty and has an average N-gain of the three classes in the moderate category. In the scientific literacy test questions, the form of complex multiple choice questions is spread across indicators K1, K2, and K3. So that it can be said that students have difficulty solving questions with complex multiple choice forms compared to other forms of questions. Complex multiple choice questions are more difficult than regular multiple choice questions. because in completing it students must take several stages to choose more than one correct answer. The form of complex multiple choice questions is able to measure students' abilities up to the evaluation stage and can train students to master the material in a complex and comprehensive manner(Jannati et al., 2022; Wijaya & Dewayani, 2021).

In terms of students' mastery of learning in scientific literacy skills (Figure 4.15), it was found that the percentage of students' completeness classically in the three successive classes was 100% (class A), 91% (class B), and 86% (class C). . These results are in accordance with the effective criteria according to the Ministry of National Education (2012) which states that a learning device is said to be effective if the percentage of completeness of students' learning outcomes classically for each class is ≥85%. Thus, the developed TPACK integrated problem-based learning model learning tool has succeeded in training or improving students' scientific literacy skills on global warming material.

The success of learning tools in improving students' scientific literacy skills is supported by the implementation of learning and student activities during learning which are classified as good and very good. As a result, each phase of the problem-based learning model succeeds in realizing meaningful learning for students. This is in accordance with constructivism learning theory which states that if the knowledge is built by the learner (students) it will produce meaningful learning, so that the knowledge found will be easily remembered and easily transferred from previous learning outcomes in order to solve problems.(Fahrurrozi and Mohzana, 2020). In problem-based learning or problem-based learning supports students to interact with teachers or peers who know more, so that students will reach a level of development that is slightly more than their intellectual abilities, namely potential development. Teachers who use problem-based learning prioritize the active participation of students, are inductively oriented, find or build students' knowledge rather than giving students ideas or theories about the world(Azizah et al., 2020; Sunarti & Septiana, 2019).

Based on the description above, it can be concluded that the learning tools that have been developed are effective in improving students' scientific literacy skills. Effective because it can improve students' scientific literacy skills, where in this study the increase was in the high category. The implementation of learning, student activities and obstacles that can be overcome during learning are also the basis for the tools that have been developed to be effective. This result is also supported by the criteria for the effectiveness of learning devices which state that, learning devices are said to be effective if these devices can achieve the expected results (Mahlianurrahman, 2020; Nieveen & Folmer, 2013; Syafitri et al., 2021).

2. Problem Solving Skills

Based on the discussion of the validity of the learning device, the problem solving test sheet was declared theoretically valid, namely by the expert and empirical assessment based on the results of the test questions (Appendix 4.6).The results of students' problem solving tests are known through the pre-test and post-test. Pre-test questions were given to students before being given treatment with the aim of knowing students' initial abilities. While the post-test questions were given after treatment with the aim of knowing the effect of the treatment on students' problem-solving skills. The problem solving test consists of five essay questions or descriptions of problem solving on global warming material. Each problem-solving test item measures four indicators of problem-solving skills, namely 1) understand the problem; 2) make a plan (devise a plan); 3) carry out the plan (carry out the plan); and 4) looking back (looking back).

The distribution of pre-test and post-test scores on the problem solving skills test is presented in Table 4.19. The results obtained show the same results as the results on the scientific literacy test, namely the minimum score on the pre-test is different from the post-test, with the results of the post-test minimum score being greater than the pre-test as well as the maximum score. This shows that students' post-test scores are better when compared to pre-test scores (Hidaayatullaah et al., 2020; Suprapto et al., 2021). Therefore, the distribution of data between the pre-test and post-test problem solving skills test is also different.

To find out whether there is a difference between the pre-test and post-test scores, an inferential statistical test is performed. The technique used is the Paired Samples Test. Because the pre-test and post-test values fulfill the assumption test (normality test). In accordance with the results of the normality test using the Kolmogorov-Smirnov presented in table 4.20, it shows that the pre-test and post-test values in class A, B, and C have a significance value above 5% or (Sig.) > 0.05. This means that the distribution of pre-test and post-test data for the three classes is normally distributed. Because the test results fulfill the assumption test, to analyze the significance of the pre-test and post-test scores, parametric statistics (Paired Sample T-test) are used.(Sugiyono, 2019; Yeager, 2022).

The results of the Paired Samples Test are presented in Table 4.22, showing that class A, B, and C show Sig. (2-tailed) ie 0.000 less than 5% (< 0.05). If the value of Sig. (2-tailed) < 0.05 then H0 is rejected and Ha is accepted(Santoso, 2018). So, it can be said that there is a significant difference (meaning) between the pre-test and post-test scores. Thus, it can be interpreted that there is a significant difference between students' problem solving learning outcomes in the pre-test and post-test data from the three classes. This shows that there is an influence from the implementation of learning with learning tools that have been developed on improving learning outcomes (post-test) of class A, B, and C students.

Furthermore, to determine the consistency of the pre-test and post-test values of the three classes with normally distributed data, a parametric statistical test One Way ANOVA was performed, which aims to determine whether the average of the three classes is significantly different or not. The group or class assumption before conducting the One Way ANOVA test is that the groups have the same variance (homogeneous) and the data is normally distributed. The homogeneity assumption test is presented in Table 4.21, which states that all sample data or research groups have the same variance (homogeneous) with the Sig value. based on a mean of 0.340, meaning greater than 5% (> 0.05). The results of the One Way ANOVA test on the N-gain problem solving skills of students from the three classes (Table 4.24) show the value of Sig. of 0.291, meaning greater than 5% (> 0.05).

To find out the difference between the pre-test and post-test values, it can be analyzed using the average normalized gain both in terms of the N-gain for each student, based on each problem solving indicator, and item items. Table 4.24 presents the N-gain of students' problem solving skills from the three classes. Overall, the average N-gain was obtained for the three classes, namely in the high category, namely class A (0.72), class C (0.70), and in the medium category, namely class B (0.69). Meanwhile, the N-gain score based on indicators of problem solving skills is presented in Figure 4.17. It is known that the three classes have an increase in gain in the high and medium categories. The indicator of understanding the problem in class A and C has an increase in the high category, while class B is moderate. The indicator for making a plan (devise a plan) is only class B which has an increase in the high category (classes A and C are in the medium category). The indicator of carrying out the plan (carry out the plan) of improvement is in the medium category in class B and in the high category, namely class A and C. The increase in the indicator looks back at the process and results (looking back) of the three classes, namely moderate. This shows that students are still weak in evaluating or re-checking the process and results of the problem-solving process that has been carried out. In line with research by Tanti et al. The indicator of carrying out the plan (carry out the plan) of improvement is in the medium category in class B and in the high category, namely class A and C. The increase in the indicator looks back at the process and results (looking back) of the three classes, namely moderate. This shows that students are still weak in evaluating or re-checking the process and results of the problem-solving process that has been carried out. In line with research by Tanti et al. The indicator of carrying out the plan (carry out the plan) of improvement is in the medium category in class B and in the high category, namely class A and C. The increase in the indicator looks back at the process and results (looking back) of the three classes, namely moderate. This shows that students are still weak in evaluating or re-checking the process and results of the problem-solving process that has been carried out. In line with research by Tanti et al.(2021)that on the indicator of re-examining the process and results, students' skills are needed to see and reflect back on what has been done or look back at various existing solutions.

The increase in the problem solving N-gain score obtained by students differs from one another. This difference is because students who are active and enthusiastic in learning and in carrying out tests have different characteristics. In addition, behavior during the learning process is lacking in providing guidance to students in working on questions. Jufrida et al.(2019)said that there are several factors that influence student learning outcomes, namely psychological factors (student motivation and interest in learning), family factors (educational background and parental guidance), school factors (teacher teaching methods, teaching materials or learning media, infrastructure), and other learning activities.

An overview of students' problem-solving improvements based on the items is presented in Figure 4.18. It can be seen that the items that have N-gain scores are in question number 1. Meanwhile, the two items with the lowest increasing scores of the 5 questions given are in questions number 4 and 5. Overall the N-gain category of problem solving is based on the item which are in the medium and high categories. In the high category on questions 1 and 3 and in the moderate category on questions 2, 4 and 5. This is in line with Figure 4.19 regarding the percentage of students' difficulties in working on problem solving questions. Question number 1 has a difficulty level of 20.33%. This means that of the five questions, students are easy to work on question number 1. Question number 1 is a matter of solving a problem in the form of the impact of using mosquito spray on global warming. The highest level of difficulty for students in working on problem solving tests is on question number 5 with a difficulty level percentage of 38%. Problem number 5 is a question regarding the experiment of molecules and light through PhET Simulation, where students are asked to analyze the results of the experiment based on the experimental table and its relationship to greenhouse gases.

When viewed from the learning completeness of students in problem solving skills (Table 4.25), it is found that the percentage of students' completeness classically in the three classes in a row is 84% (class A), 71% (class B), and 75% (class C)). These results are not in accordance with the criteria for effectiveness according to the Ministry of National Education (2012) which states that a learning device is said to be effective if the percentage of complete classical learning outcomes for each class is ≥85%. This is because in one lesson the teacher teaches and requires students to master two skills, namely scientific literacy and problem solving. Besides that, there is a lack of time in implementing learning tools to get maximum results. Even though the classical completeness of students in each class is less than 85%, but the average increase in problem solving skills of students in the three classes is in the high category. Thus, the developed TPACK integrated problem-based learning model learning tool has succeeded in training or improving students' problem-solving skills on global warming material.

The success of learning tools in improving students' problem solving skills is supported by the implementation of learning and student activities during learning which are classified as good and very good. As a result, each phase of the problem-based learning model succeeds in realizing meaningful learning for students. This is in accordance with constructivism learning theory which states that if the knowledge is built by the learner (students) it will produce meaningful learning, so that the knowledge found will be easily remembered and easily transferred from previous learning outcomes in order to solve problems. In problem-based learning or problem-based learning supports students to interact with teachers or peers who know better,

In line with the results of research conducted by Siregar et al.(2022)which states that the TPACK-based problem learning model makes learning more meaningful and the learning outcomes of junior high school students experience classical mastery. In addition, TPACK-based learning is an effective learning in physics learning activities and the development of learning media that can improve HOTS and students' scientific attitudes.(Ilmi et al., 2020). The application of the problem-based learning model also has a positive effect on students' problem-solving skills, where the activity of students' problem-solving skills in the experimental class is higher than that of the control class.(Gustia et al., 2019). Along with a good understanding of concepts, students' skills in problem solving will also increase. Evidenced by the increase in post-test results of the three classes.

Based on the description above, it can be concluded that the learning tools that have been developed are declared effective for improving students' problem-solving skills. This result is also supported by the criteria for the effectiveness of learning devices which state that, learning devices are said to be effective if these devices can achieve the expected results (Mahlianurrahman, 2020; Nieveen & Folmer, 2013; Syafitri et al., 2021). In this case, the expected results are to improve students' problem solving skills related to global warming material, the implementation of learning goes very well when implemented using the developed tools, student activities run well and very well, and obstacles during learning implementation can be overcome properly .

3. Student Response

Response questionnaires can be used to find out how students feel about learning with the developed learning tools. Twelve questions were given to students in the response questionnaire. The results of student responses in each class can be seen in Appendix 4.9 and Figure 4.20. from these results it can be seen that students gave very good positive responses to learning using the TPACK integrated problem-based learning model learning tool. Where these learning tools can foster motivation, interest, and interest in studying global warming material. In addition, through learning using the devices that have been developed also provide good benefits for students.

Students say that the problem-based learning model and TPACK integrated learning process can encourage students to want to take part in the learning process because according to them the learning process is interesting and not boring. Students who are enthusiastic about participating in learning activities are more likely to have curiosity, and are more likely to ask questions to the teacher so that it is easier to understand and master the material when the teacher gives an explanation. This can be seen through the categories of student responses to the questionnaire response to questions from the first to the fifth, the three classes have a very good percentage of responses. This is in line with Bandura's learning theory,(Lesilolo, 2019).

By forming groups, it is easier for students to learn and discuss with their group mates while working on LKPD and it is easier to identify problems, formulate problems, make hypotheses, identify variables, collect data, analyze data, make conclusions, and present work. However, maximum results were obtained or were in the good category. This is due to the limited time in working on LKPD and working together in groups. So that the work on LKPD in groups is continued as homework. LKPD with a model like the one developed by the researcher is considered a new thing for students, so that in learning many students don't know how to do it. The good category is also found in questions about swarm-up material with the TPACK integrated problem-based learning model, making me more trained to solve problems in everyday life. This is because students have never been directly involved in facing the impact of problems in their lives.

Handouts, LKPD, evaluation sheets integrated with current developments, can be accessed online making it easier for students to learn. In addition, students find the learning environment, teaching methods, and stages of instruction to be very novel and interesting. This is because teachers still teach using conventional methods and rarely use experiments as a means of supporting learning. TPACK integrated learning using the Problem Based Learning learning model can require students to find material concepts in groups through discovery activities. In accordance with the LKPD guidelines, this discovery activity is complemented by a practicum. This is in line with the opinion of Magdalena et al.(2020)which states that effective teaching materials must be able to arouse students' interest and increase their motivation to learn more so as to improve their skills.

Based on the description above, it can be concluded that the learning tools that have been developed are effective. These results are supported by the effectiveness criteria of learning tools according to Nieveen et al. (2013) which states that a learning device is said to be effective if the device can achieve the expected results. In this case, the expected result is a very good response to the learning tools that have been developed, with an average response percentage of the three classes of 84.75%. In addition, it is also supported by the criteria for the effectiveness of learning devices according to Mahlianurrahman (2020) that the earth science learning tool that has been developed is declared effective if the percentage of student responses is $\geq$ 61%.

CHAPTER VI
CLOSING

A. Conclusion

Based on the research results obtained, the research can be concluded as follows:

1) TPACK's integrated learning tools with the problem-based learning model in improving scientific literacy and problem-solving skills that have been developed are declared valid, in terms of content (content), construct (presentation), and language criteria.
2) TPACK's integrated learning tools with the problem-based learning model in improving scientific literacy and problem-solving skills that have been developed are declared practical, because:
   a. The level of implementation of learning with learning tools that have been developed is in the good and very good categories.
   b. The overall activity of students when learning uses learning tools that are developed in good and very good criteria.
   c. Obstacles found during the implementation of the developed learning tools can be overcome so that the learning process achieves the expected goals.
3) TPACK's integrated learning tools with the problem-based learning model in improving scientific literacy and problem-solving skills that have been developed are declared effective, because:
   a. The level of scientific literacy of students after participating in learning has increased, with an average N-gain of 0.75 which is classified in the high category.
   b. The level of problem solving skills of students after participating in learning has increased, with an average N-gain of 0.70 which is classified in the high category.

c. The response of students after participating in learning using the learning tools that have been developed is very good, with an overall average percentage of responses of 84.75%.

B. Suggestions

Based on the results of the research, some suggestions can be given as follows:

1) Teachers use this learning tool on global warming material
2) In implementing this learning tool, the thing that needs to be considered is that the teacher should guide intensely at every step of learning for students who have never received problem-based learning.
3) When students access LKPD and evaluation sheets online, make sure the school has a good internet network, so students can work on LKPD and evaluation sheets smoothly.
4) Teachers or other researchers can continue this research by developing TPACK integrated learning on global warming material by practicing skills other than those carried out in this study.

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