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TPACK-Based Project-Based Learning Model Development to Improve the Four C's Students' Skills

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research aims: 1) to know the description of the needs of the TPACK-based PjBL model; 2) to produce a TPACK-based PjBL model design; 3) to know the feasibility of developing a TPACK-based PjBL model; 4) to know the practicality of the TPACK-based PjBL model; 5) to know the effectiveness of the TPACK-based PjBL model to improve the Four Cs skills of PGSD students at Muhammadiyah University Enrekang. The research and development design uses the Plomp model which consists of preliminary research, prototyping phase, assessment phase. The data collection techniques used were Questionnaire Techniques, and Observation. The research instrument used a learning device validation sheet, a learning implementation observation instrument, a student response instrument, a four Cs skills assessment instrument. The results showed that it was necessary to develop a TPACK-based PjBL model to improve students' four Cs skills. The design of the PjBL-TPACK model in the form of a model book, SAP, LKM, and several research instruments

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was declared very valid based on expert judgment. The results of the practicality test showed that the TPACK-based PjBL model was proven to be very good, based on the results of observation and implementation of learning and student response questionnaires. Furthermore, the results of the effectiveness test through the assessment of students' four Cs skills show that there is a significant difference in the application of the PjBL model with the TPACK-based PjBL model on four cs skills between PGSD class A students and PGSD class B students.

Keywords: PjBL; TPACK; four Cs skills.

1. INTRODUCTION

The biggest challenge faced by the government in the field of education is *Education Technology* in the 21st Century. The occurrence of a 21st century educational paradigm shift is the impact of significant developments in communication technology in the Digital era [1] which has an impact on the world of education. Therefore, students are expected to develop "*Learning by Activities*" which aims to produce students who have Four Cs skills (*critical thinking and problem solving, communication, collaboration, creativity, and innovation*).

The Four Cs skills are an essential component of 21st century education that equips students with the ability to think deeply, solve problems effectively, communicate clearly, cooperate productively, and innovate and create. The development of these skills is not only important in the academic context, but also vital in preparing students to face complex challenges in the future, both in professional and personal life [2–4]; The Partnership for 21st Century Skills. Therefore, the PGSD Study Program at FKIP UNIMEN as one of the Educational Personnel Education Institutions (LPTK), of course, expects each of its graduates to be able to answer challenges by having the Four Cs skills. So that the learning process in higher education is expected to contribute to the mastery of skills in accordance with technological and scientific developments [5].

In 21st century learning, teachers are required to have TPACK (*Technological, Pedagogical, Content Knowledge*) knowledge that can integrate technology, pedagogy and content in learning [6]. Several studies that discuss the TPACK ability of teachers and prospective teachers have been conducted. Most studies focus on measuring TPACK ability [7] and measuring teachers' perceptions of TPACK [8]. The results of these studies mostly show that the TPACK ability of prospective teachers is still not good, especially in Asian countries. Although technology integration in education is increasing, there are still gaps in its implementation. According to [9] the competence of prospective teacher students in the implementation of learning is lowest in lesson planning and technology utilization. From these results, it can be concluded that the pedagogical competence of prospective teachers in LPTK still needs to be improved. Therefore, the development of TPACK-based learning models is needed to improve the competence of prospective teachers, especially in terms of lesson planning and technology utilization. This is important to prepare future teachers who are able to integrate technology effectively in the learning process.

Given the important role of teachers in preparing students to have Four Cs skills, a creative effort is needed in designing an innovative learning model, where students will be made the center of learning (*student-centered learning*), so that they become more active and creative in developing Four Cs skills by integrating TPACK which emphasizes the relationship between the constituent components that are integrated between content, pedagogy and technology in the context of learning. So, it is expected that students will be able to improve Four Cs skills. One of the suitable models is the Project-Based Learning (PjBL) model.

Muhria [10] states that the *Project Based Learning* model is a learning model that provides opportunities for educators to manage learning in the classroom by involving project work. This can be done through the introduction of various knowledge and skills using technology and then honing their skills in communicating and solving problems (Bell, 2010) in [11]. The success of PjBL is because the activities that students do are authentic and have a strong connection to the real world. Learning skills and concepts in a real context produces relevant and meaningful learning, so that students can apply the skills and concepts they get directly and not only understand at the level of theory. Therefore, the

selection of this model aims to guide students in a collaborative project that integrates various subjects (materials) of the curriculum, provides opportunities for students to explore content (materials) using technology, and conduct experiments collaboratively.

Certainly, The Four Cs skills—Critical Thinking and Problem Solving, Communication, Collaboration, and Creativity and Innovation—are essential for students to develop in the 21st century. Here are some specific examples to illustrate each of these skills:

Critical Thinking and Problem Solving:

- **Critical Thinking**: Students can analyse complex information, evaluate evidence, and form well-supported conclusions. For example, in a science class, students might analyze data from an experiment to determine the cause of a phenomenon.
- **Problem Solving**: Students can identify problems, generate solutions, and implement them effectively. For instance, in a math class, students might solve a real-world problem like calculating the cost of materials for a construction project.

Communication:

- **Effective Communication**: Students can convey ideas clearly and persuasively through various media. For example, in an English class, students might write a persuasive essay or create a presentation to argue for a particular point of view.
- **Active Listening**: Students can understand and respond appropriately to verbal and non-verbal cues. For instance, in a group discussion, students might listen attentively to their peers and respond thoughtfully.

Collaboration:

- **Teamwork**: Students can work together to achieve a common goal. For example, in a project-based learning activity, students might collaborate to create a multimedia presentation on a historical event.
- **Conflict Resolution**: Students can manage conflicts and maintain positive relationships within a team. For instance, in a group project, students might resolve disagreements over the direction of the project by finding a compromise.

Creativity and Innovation:

- **Creative Thinking**: Students can generate new ideas and solutions. For example, in an art class, students might create an original piece of art that reflects their unique perspective.
- **Innovation**: Students can apply creative ideas to real-world problems. For instance, in a technology class, students might design and develop an innovative solution to a common problem, such as creating a smart home device.

These examples illustrate how the Four Cs skills are essential for preparing students to succeed in the 21st century, where they will face complex challenges that require critical thinking, effective communication, collaborative problem-solving, and innovative solutions.

2. METHODOLOGY

The type of research used in this research is Plomp model development research which consists of (1) *preliminary research*, (2) *prototyping phase*, and (3) *assessment phase* Plomp, 2013 in [12]. The type of data in this study is, namely data obtained from expert results including validation of model books, SAP, LKM and research instruments. The product design was then tested on the implementation of the usage trial in the form of 1) observation results of learning implementation, 2) students' four Cs skills, 3) student responses to the TPACK-based PjBL model. The quality of the product design of the development model is based on the criteria of validity, practicality and effectiveness. Testing the effectiveness of the development model product is done by looking at the value of the student's *Four Cs* skills, then interpreting the student's *Four Cs* skills referring to Table 1.

To test the difference in the application of the learning model using an independent t-test on the improvement of students' Four Cs skills, an analysis requirement test was first carried out using SPSS 29 software.

Table 1. Four Cs Skill Assessment Categories

Interval	Category	Description
75 < PK ≤ 100	Very good	Exemplary student skills that exceed the standard
50 < PK ≤ 75	Good	Students' skills have met the standard targeted in each lesson.
25 < PK ≤ 50	Not good	Student skills that have not reached the standard
0 < PK ≤ 25	Not good	Student skills are not up to expectations and require significant support

Source: [13]

3. RESULTS AND DISCUSSION

3.1 Model Development Needs Analysis

The results of observations and interviews that have been conducted at the PGSD FKIP UNIMEN Study Program in Enrekang Regency obtained data that generally lecturers tend to use technology in a limited way and more often as a passive teaching aid, such as the use of PowerPoint for material delivery, rather than as a tool for constructing critical thinking through simulation, modeling, or interactive data analysis. This is certainly not in accordance with the demands of the UNIMEN FKIP PGSD Curriculum based on Outcome Based Education (OBE), which emphasizes the sustainability of the learning process in an innovative, interactive, and effective way. so that the profile of graduates of the S1 Primary School Teacher Education Study Program can be achieved.

To prepare students as future educators, researchers, and edupreneurs, and have competencies that are in accordance with the needs of the times. As a digital native generation, PGSD students generally tend to adopt technology in learning. This is in line with the concept of Technological Pedagogical Content Knowledge (TPACK) introduced by [6] that understanding and mastering TPACK is important for PGSD students to be able to integrate technology effectively in their future teaching practices.

Based on this analysis, it shows that the chosen course design is Media and Learning Resources in SD by considering the characteristics and needs of PGSD students. Therefore, the development of learning models that accommodate cognitive development, diversity of learning styles, technological skills, social-collaborative aspects, and the development of pedagogical competencies and Four Cs skills must be well reflected in the CPMK and Sub-CPMK formulated. One of the learning designs that is in accordance with the characteristics of the course and PGSD students is the Project-based learning (PjBL) model. Through the PjBL-TPACK model, students can solve problems related to media and learning resources in SD critically, creatively, and innovatively. It is certainly expected that students will be able to develop collaborative learning interaction patterns so that student communication skills can also develop optimally.

Project activities in the PjBL-TPACK model become a forum for accommodation of students' four Cs skills so that learning will be more in-depth and applicable. This is very logical because students not only gain theoretical and practical understanding of the application and development of technology-based SD media and learning resources but also develop the essential abilities needed for professional success as prospective SD teachers in the digital era so that they are able to compete in the future.

PjBL-TPACK Model Design: The model design of the PjBL-TPACK model was developed based on the results of preliminary research through needs and context analysis and the results of the literature review. [14] mentioned that a model has main components, namely syntax, social system, reaction principles, support system and instructional impact and accompanying impact.

The syntax of the PjBL-TPACK model was developed based on the results of the analysis of the weaknesses of the PjBL model, then minimizing these weaknesses by integrating the Technological Pedagogical and Content Knowledge (TPACK) framework into the learning process. Based on the results of this analysis, the syntax of the hypothetical model (PjBL-TPACK) to improve students' four Cs skills consists of 6 stages including 1) Orientation, 2) Fundamental questions, 3) Designing and Developing project schedules, 4) Monitoring project implementation, 5) Project presentation and assessment, and 6) Reflection.

The social system in this model is built by forming small groups so that students in the group will collaborate and communicate together in working on projects. Discussions that occur in the group will stimulate students' thinking to think critically in dealing with the problems given. While the reaction principle is that the lecturer provides constructive feedback to students regarding the project to be worked on. This feedback is not only about the final product, but also about how pedagogical skills and content can be integrated into the learning process, use of technology, and applications.

The instructional impact of this PjBL-TPACK model is (a) students can examine the concepts of media and learning resources in SD, namely students are able to apply concepts and design media and learning resources in SD, (b) students are able to find, analyze and provide solutions to learning problems in SD through the development and utilization of SD media and learning resources in accordance with the characteristics of students, and (c) students are able to apply innovative ICT-based media and learning resources, especially in the life of the world of education as a professional teacher's duty in SD. While the accompanying impact of this PjBL-TPACK model is the increasing skills of the Four Cs, namely critical thinking, creativity, collaboration and communication and the ability to use technology in developing ICT-based learning media through this learning. The supporting systems needed in the PjBL-TPACK model include 1) Lecture Program Unit (SAP), Teaching Materials and 3) Student Worksheet (LKM).

Feasibility of PjBL-TPACK Model: The feasibility test of the model by experts or expert judgment aims to assess the feasibility of the PjBL-TPACK model and its supporting devices from experts in their fields. Prior to the feasibility test by experts, researchers conducted a self-evaluation of the model book, SAP, LKM, and the four Cs skills assessment sheet to investigate errors that occurred. From the results of this self-evaluation, it was found that it needed to be revised to ensure that each component had met the assessment indicators.

Product validation of the PjBL-TPACK model was assessed by experts. After the final validation is carried out to the validator, data analysis is then carried out based on the value given by the validator. The results of the assessment of the two experts on the product design of the TPACK-based PjBL model to improve students' four Cs skills can be seen in Table 2.

Based on Table 2, the product design of the PjBL-TPACK model to improve students' four Cs skills is categorized as very valid, so the PjBL-TPACK model design product is suitable for use in research. Furthermore, formative evaluation is carried out at the stage of *one-to-one evaluation*, *small group evaluation, and field test*. For more details, it can be displayed in Table 3

Table 2. Results of expert validation of the PjBL-TPACK Model

Validator	Model Book	SAP	LKM	Student Response Questionnaire	Observation of learning implementation	4Cs Skills Assessment
Expert 1	77,3 Valid	83,75 Very Valid	80,77 Very Valid	87,5 Very Valid	78,3 Valid	81,25 Very Valid
Expert 2	91,1 Very Valid	97,5 Very Valid	98,1 Very Valid	95 Very Valid	83,3 Very Valid	96,5 Very Valid

Table 3. Formative evaluation result data

Evaluation	Student Response Questionnaire	Observation of learning implementation	4Cs Skills Assessment
One to one	83,3 Very Practical	84,61 Very Practical	-
Small Group	83,69 Very Practical	87,6 Very Practical	78 Very good (Over standard)

Table 4. Implementation Observation Results at the *field test* stage

No.	Meeting	Average Assessment Results (%)			
		PGSD A	Category	PGSD B	Category
1	Meeting 1	78,85	Practical	79,81	Practical
2	Meeting 2	85,58	Very Practical	86,54	Very Practical
3	Meeting 3	93,27	Very Practical	94,23	Very Practical
	Average	85,90	Very Practical	86,86	Very Practical

Table 5. Results of Student Response Questionnaire Analysis at the *field test* stage

No.	Assessment Aspect	Average Assessment Results (%)			
		PGSD A	Category	PGSD B	Category
1	Ease of following the TPACK-based PjBL model	81,4	Very Practical	81,67	Very Practical
2	Benefits of TPACK-based PjBL model	83,09	Very Practical	83,18	Very Practical
3	Implementation of the TPACK-based PjBL model	83,33	Very Practical	83,88	Very Practical
4	Lecturer's role in learning	88,75	Very Practical	89	Very Practical
	Average	84,14	Very Practical	84,43	Very Practical

Table 6. Comparison of Students' Four Cs Skills Assessment Results

Meeting.	*Critical Thinking & Problem Solving*		*Creativity & Innovation*		*Collaboration*		*Communication*	
	PGSD A	PGSD B	PGSD A	PGSD B	PGSD A	PGSD B	PGSD A	PGSD B
1	72,5	73,1	74,5	74,8	79,3	82,7	76,3	78,7
2	75,0	75,0	78,6	79,3	82,8	84,3	80,8	80,4
3	82	84	83,9	83,8	86,5	86,1	84	85
Average	76,5	77,4	79	79,3	82,9	84,4	80,5	81,4
category	Very good	Very good	Very good	Very good	Very good	Very good	Very good	Very good

3.2 Practicality of the PjB -TPACK Model

The field test stage was carried out to obtain data on the practicality of the PjBL-TPACK model to improve the four Cs skills. Data obtained from the results of observations of the implementation of the PjBL-TPACK model and the Student Response Questionnaire to the PjBL-TPACK model. The following is the data on the results of observations of the implementation of the PjBL-TPACK learning model to improve the skills of four Cs students of the PGSD FKIP UNIMEN Study Program.

The data in Table 4 shows the average score of learning implementation in PGSD A class of 85.90 and 86.86 for PGSD B with very practical criteria for all aspects of the assessment, this means that all aspects observed are in very practical criteria.

Data on the results of student responses to the PjBL-TPACK model were conducted to determine student opinions about the implementation of the PjBL-TPACK model. Data on the results of student responses to the PjBL-TPACK Model can be seen in Table 6.

Based on Table 5, it shows that the percentage of the average score is 84.14 for PGSD A and 84.43 for PGSD B respectively with a very practical category. This means that the PjBL-TPACK model makes it easier for students to carry out projects because it is assisted by LKM and teaching materials that are easily accessible to students.

3.3 Effectiveness of PjBL - TPACK Model

To find out the increase in students' Four Cs skills after the application of the PjBL-TPACK model, it can compare the average score of four cs skills obtained at each meeting with the two classes that are sampled. The data on the results of the assessment of students' four Cs skills can be seen in Table 6.

Based on the data from the assessment of students' four Cs skills after applying the PjBL-TPACK model, it shows a significant increase with the achievement criteria exceeding the standard so that it is exemplary. The effectiveness of the PjBL-TPACK model was carried out with an independent sample t-test. The results of the independent sample t-test test obtained sig value. = 0.530 > 0.05. Thus, H0 is accepted. So, it can be concluded that there is no significant difference in the application of the PjBL-TPACK model on four cs skills between PGSD A and PGSD B students.

The PjBL-TPACK model was developed as a place to develop students' Four Cs skills so that one of the parameters of the model's effectiveness is the four Cs skills. The results of data analysis showed that students' Four Cs skills in the four aspects assessed showed significant achievement with categories exceeding the standard (very good).

Critical thinking and problem-solving skills are developed through challenging the fundamental questions that are the focus of the project. Through fundamental questions, students are trained to find solutions to complex problems. This, of course, requires the ability to formulate hypotheses, plan research, and test proposed solutions. To achieve the project objectives, students must be able to reach agreement and appreciate different points of view through discussion activities. These discussions allow students to see problems from multiple perspectives, test new ideas, and work collaboratively to find effective solutions. So, this skill is very valuable for PGSD students who will later become professional teachers.

Creative thinking skills (creativity and innovation) in the PjBL-TPACK model are developed when students identify the problem to be solved. At this stage, students develop their thoughts to design the project and develop a schedule to complete the project. The activity of designing the project design is carried out in collaboration between students and lecturers. In this activity, the lecturer carried out the following activities: (1) Include rules in making projects; (2) Select learning activities; (3) Create learning activity objectives; (4) Create instructions that guide student performance in project completion; (5) Include tools and materials that can be accessed by students to help complete the project. In relation to preparing a schedule, students are expected to be able to divide tasks in a structured manner so that later the project can be completed on time. To facilitate schedule management, the use of technology such as the Trello application can increase the effectiveness of group work. This is in line with what was done by [15] the use of technology in designing projects facilitates creative and critical thinking. Technology as a tool to develop innovative ideas and solve problems in new ways.

The PjBL-TPACK model provides opportunities for students to collaborate (collaboration) so that they can construct their knowledge through project activities. The social interaction that occurs through group work encourages students to share and accept views from fellow group members. The use of digital technology such as online discussion forums and project management applications (Trello) helps students learn to work together more effectively. This is in line with the research study conducted by [16] that the technology-based PjBL Learning model has been shown to increase the efficiency of collaboration between students. The increase indicates that the PjBL model not only provides academic knowledge, but also facilitates the development of collaboration skills. The utilization of online learning platforms such as google classroom and digital communication tools (WhatsApp, Trello) helps students to coordinate better and share information efficiently, which contributes to the quality of project outcomes and the overall learning experience.

Communication skills are developed in group discussion activities, presentation of project results and presentation of project results. The intended communication is both oral and written communication. Oral communication occurs when students discuss in groups and when presenting the results of their work. This activity facilitates students to develop their ability to express their opinions and listen to the views of others. Meanwhile, written communication is developed when students express their ideas, ideas and creative thinking in compiling problem

solutions in written form. Posters, or PowerPoint slides. The MFI as a support system for the PjBL-TPACK model has been designed to encourage students' communication skills. This communication also increases with the use of media and technology in conveying information. The utilization of Google Meet media and Trello applications as well as communication media and presentation media (google slides) has been used by students to convey their messages and ideas.

4. CONCLUSION

The developed PjBL-TPACK model has a syntax of Orientation, 2) Fundamental questions, 3) Designing and Developing a project schedule, 4) Monitoring project implementation, 5) Project presentation and assessment, and 6) Reflection. The developed PjBL-TPACK model has been tested valid and practical for use in learning. The developed PjBL-TPACK model is also proven to be able to improve the four Cs skills of prospective elementary school teachers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

CONSENT

As per international standards or university standards, respondents' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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