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Development of PJBL-Based Physics Edu Media to Improve The 21st Century Learning Skills of High School Students

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Abstract

The purpose of this research was to create physics teaching resources that would enhance students' 21st century skills in renewable energy. The R&D approach was used in conjunction with data collection methods including both test and non-test modes. This study involved three validators who assessed the learning materials from the perspectives of both material and media aspects. According to the assessment results, the material aspect received a rating of 'very good,' whereas the media aspect scored 'good.' The enhancement of 21st century learning competencies was gauged through pretest and posttest evaluation, revealing a rise in critical thinking, creativity, communication, collaboration, use of ICTs, as well as life and career skills. The study determined that the PjBL-Based Physics Edu learning materials could serve as a reliable instructional tool for teaching renewable energy topics with moderate effectiveness.

Keywords: 21st century competencies, physics edu media, PjBL

INTRODUCTION

In the 21st century, information and communication technology have become essential to every area of life, including education. The existing education system priorities cultivating specific competencies to aid economic growth and competitiveness in the era of industrial revolution 4.0. Education plays a critical role in preparing the workforce and helping students acquire the required skills for employment (Widodo, 2016).

Trilling (2009) identified four key components necessary for preparing competent individuals: work experience, critical thinking abilities, digital technology proficiency, and research skills. These skills are collectively referred to as 21st century learning skills and should be integrated into the school curriculum to prepare graduates with the requisite abilities to confront the demands of contemporary society (Zubaidah, 2018). Mardhiyah (2021) highlights the transformation of students into skilled and valuable human resources through the acquisition of essential 21st century skills. Aslamiyah (2021) also stressed the significance of providing students with versatile skills for 21st century education to enhance their abilities. Therefore, it is imperative to implement an effective learning framework that imparts all the necessary skills for 21st century education to students.

Binkley (2012) outlines four categories of 21st century skills. The first category concerns a way of thinking, which encompasses creativity and innovation, critical thinking, problem solving, decision making, and metacognition. The second category pertains to working methods, including communication and collaboration. The third category focuses on tools for work, such as information and communication technology literacy and information literacy. The fourth category comprises life skills such as global and local

citizenship awareness, life and career development, and personal and social responsibility.

In 2018, Ariyana conducted a study suggesting that Indonesia's educational curriculum and government policies should adopt 21st century learning. Consequently, the Indonesian Partnership for 21st Century Skill Standard (IP-21CSS) was established to set a benchmark for 21st century skills in Indonesia. These abilities incorporate the 4Cs (critical thinking, creativity, communication, and collaboration), ICTs (Information, Media, and Technology Skills), personality development, and spiritual values.

According to Siska, Yufiarti and Japar's (2021) findings, the 21st century's national educational objectives involve fostering affective aspects in pupils, encouraging them to become proficient individuals and socially conscientious citizens. Similarly, Andari (2020) emphasises the significance of character development in education during the era of the Fourth Industrial Revolution. The integration of character values in the teaching and learning process is essential, as it enables students not only to acquire knowledge but also to enhance their personalities. This approach ensures that students possess both intelligence and noble character, making them valuable members of the Indonesian nation.

Acquiring the 21st century era required competencies can be a challenging task. As a result, it is vital to possess a wide range of suitable learning resources for IP-21CSS (Abidin, 2016). Research carried out by Ramdani (2019) illustrates that educators frequently use a limited variety of media in their teaching. Additionally, interviews conducted with secondary school teachers in Kendal demonstrate a shortage of media as a means of developing 21st century learning skills. Harjono's (2019) research confirms that a significant number of teachers have not yet adjusted their learning tools to meet 21st century standards. As such, they must employ creativity and innovation in lesson planning and the development of diverse media to facilitate 21st century learning. Alim, Sarwi, & Subali (2020) supported this notion, suggesting that the use of relevant learning models and habits can contribute to the development of better character and moral values in students.

Modern education ought to promote active exploration and learning among students, rather than simply dictating what they should learn (Komara, 2018). A constructivist contextual learning approach is crucial for achieving this objective, whereby students construct knowledge based on real-life situations that are relevant to them. This strategy should also equip students with critical thinking, problem solving, communication, collaboration, and technological skills, as well as meaningful learning experiences to prepare them for the challenges of the 21st century. Moreover, education should strive to cultivate graduates who are productive, innovative, and creative, enabling them to succeed in a globalised world (Aslamiah, Abbas, & Mutiani, 2021).

Project Based Learning (PjBL) is a pedagogical approach that fosters the development of students' abilities to think critically, solve problems, communicate effectively, utilise technology, and work collaboratively (Wibowo, 2014). The approach places great emphasis on the role of students in addressing significant real-world problems. Through meaningful tasks and problem-solving, students learn to create their learning strategies and produce valuable outcomes. Larmer and Margendoller (2012) emphasise crucial aspects of PjBL, such as initiating with questions or challenges, establishing motivation to acquire new knowledge, promoting critical thinking, communication, cooperation, and technical proficiency, supplying feedback and amendments, generating a publishable outcome, and empowering students to complete projects with autonomy. Experts concur that the traits of PjBL correspond with the proficiencies needed for 21st century schooling, establishing it as an apt prototype for student growth. PjBL also cultivates affirmative outlooks and cognitive competences whilst advancing media and technology expertise (Sakti, Nirwana, Nirwana, & Swistoro, 2021).

Investigations have executed PjBL at primary and advanced education echelons, as documented by Butler and Christofili (2014). Through implementing PjBL in educational settings, students can enhance their confidence, develop new skills, and increase their motivation to publish their project

results during class-based learning activities. According to Genc (2015), students are convinced that participating in project activities can effectively help them tackle a host of environmental issues while simultaneously providing them with the opportunity to acquire new experiences and learn how to find optimal solutions to the challenges they confront. Anazifa & Hadi (2016) have posited that the implementation of PjBL can heighten students' awareness of their surroundings, bolster creativity and drive long-term learning. Furthermore, Elisabet (2019) contends that adopting project-based activities can boost students' motivation to learn while simultaneously augmenting their cognitive abilities.

In the 21st century, digital learning has become synonymous with modern education (Tarigan, 2019). Rahayu's (2022) research suggests that digital learning offers an alternative approach to education with fast and convenient access to learning resources and services. Fatira, Ferawati and Darmayani (2021) propose that digital learning can be integrated into an education system that connects various educational components, rendering education more dynamic and flexible. They additionally propose the creation of effective learning materials to facilitate the digital learning experience and the achievement of desired learning outcomes.

The aim of this investigation is to produce educational resources for physics that endorse 21st century capabilities and augment knowledge of 21st century education. The objective of the study is to improve 21st century skills, including critical thinking, creativity, communication, and collaboration, as well as information, media, and technology proficiency, character development, and moral values in schools implementing the Independent Curriculum.

METHOD

This is a Research and Development (R&D) study. The research used Borg and Gall model, as shown in Figure 1.

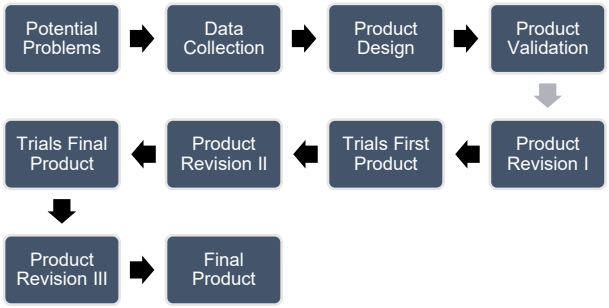

Figure 1. Research and Development (R&D) Research Design Chart

Experts in both materials and media have approved of the developed learning media. The study concentrates on high school students who access media materials. The small group test was executed on a study group of 10 students, whereas large group tests were conducted on study groups with a total of 36 students.

This study aims to enhance the 21st century learning skills, including critical thinking, creativity and innovation, communication, collaboration, ICT, life, and career skills. These competencies were measured before and after the use of the media, and the pre- and post-test scores were analysed to determine whether there was an increase in competency. Additionally, we observed students evaluate their skills for 21st century learning.

The methods of gathering information included using tests and other non-test techniques. The research investigated the effects of using physics education media through analysing student responses and evaluating the product assessment tools. The research also examined improvements and changes in 21st century skills through observation.

RESULT AND DISCUSSION

Development of PjBL-Based Physics Edu Media

The development of the PjBL-based Physics Edu media started with the creation of an application plan. The purpose of this plan was to identify the needs of schools and students. The content was created to meet the needs of the class X physics material in the independent curriculum based on project learning. The development plan includes an overview, skills acquisition, materials,

videos, infographics, quizzes, evaluations, and references.

To begin using the app, students need to click on the icon button on their phones. They will then be taken to the homepage where they can select the start button to see extracts from Surah Al Baqarah verse 30 from the holy Qur'an. There are various sections available for browsing on the main menu, including Introduction, Skills, Resources, Assignments, Examples, Tests, and Resources. The introduction talks about the decreasing energy supplies on our planet and asks students to brainstorm solutions to this problem. It also quotes a line from the Holy Quran, Al Jatsiyah verse 13. Subsequent pages display YouTube videos on the repercussions of using up fossil fuels and the energy emergency. Moreover, pupils can examine graphics that show the plenty of renewable energy sources available in Indonesia and study individually or in groups. Project activities involve creating plans for projects that will be carried out for a set amount of time. Additionally, the app offers a range of examples demonstrating the use of sustainable power practices across various regions in Indonesia. To further provide clarity, Figure 2 displays the development process for the Physics Edu media application.

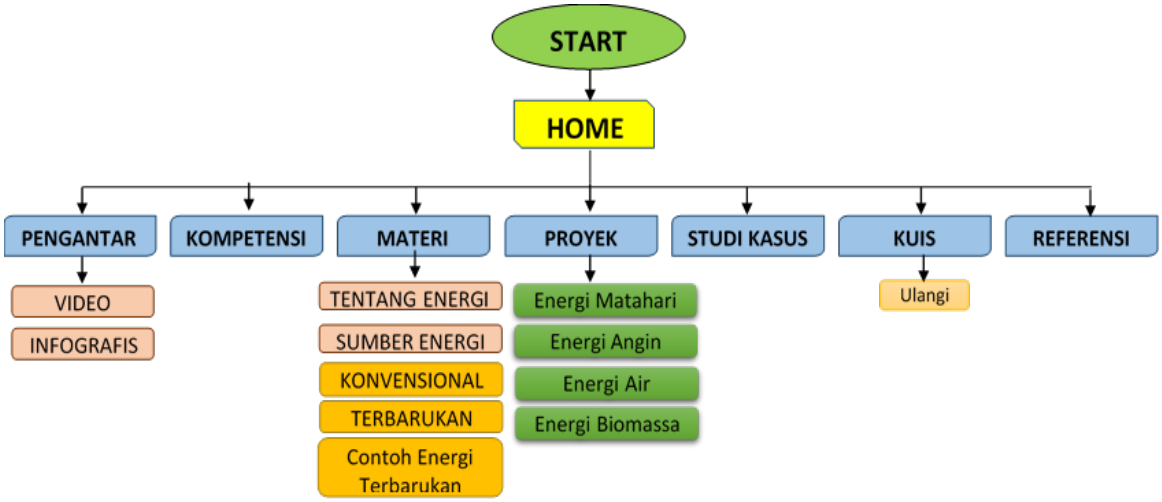

Figure 2. Scheme for Preparing Learning Media Applications

1. Application Development Stages.

The development of an application involves several stages:

A. Initial Trial.

During this stage, the media was validated by experts in physics materials and media. Experts in this context refer to educators who focus on teaching physics at the high school level. Moreover, media experts are also consulted during the initial trial. The survey by media experts uncovered these findings: design and formatting obtained an average of 80.00%, text and typography obtained 88.89%, images received 82.22%, video achieved 90.00%, packaging obtained 86.67%, while users rated 78.67%. To check the analysis of product media feasibility, refer to Figure 3.

The results of the material feasibility questionnaire, as filled out by experts, showed a 95.17% score for material relevance, an average of 98.10% for material organization, 96.00% for evaluation/practice questions, 93.33% for language aspect, and 96.00% for influence on learning process. Figure 4 displays these results.

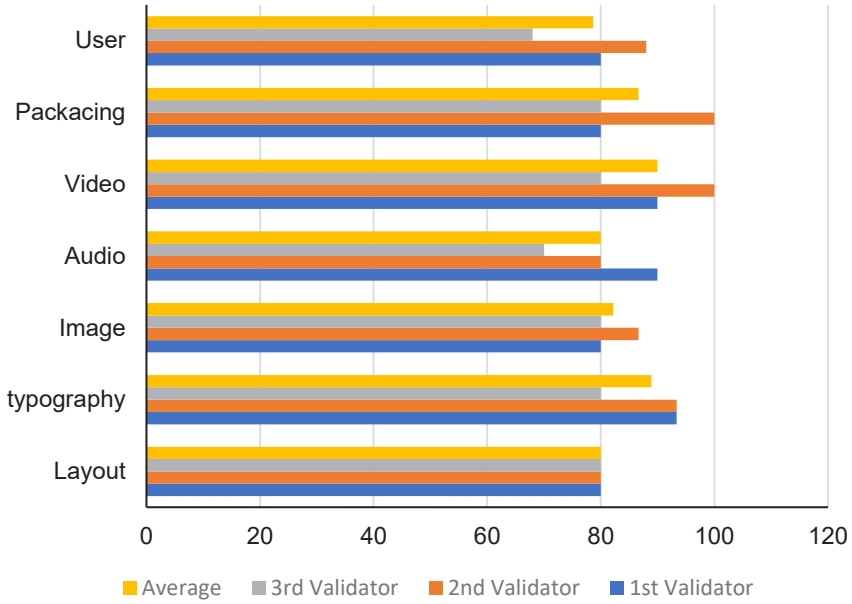

Figure 3. Results of Feasibility Analysis by Media Experts

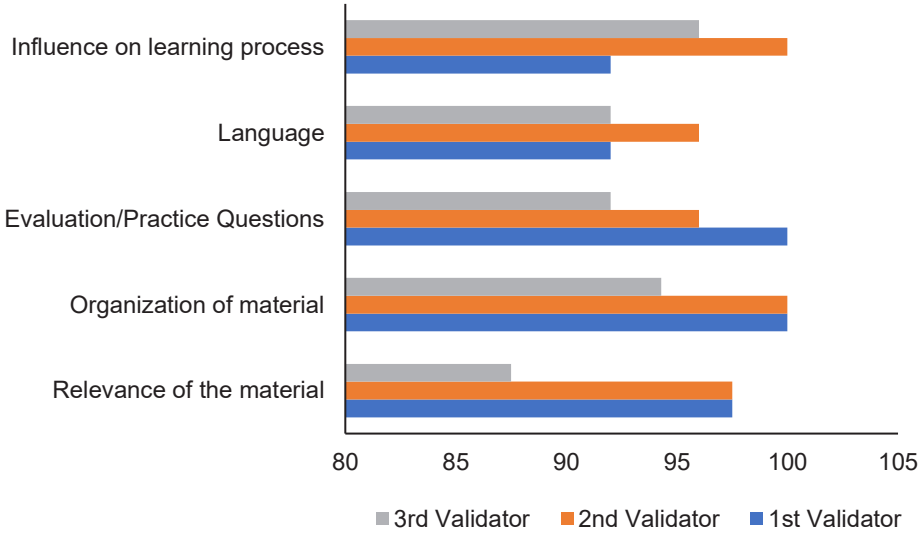

Figure 4. Results of Material Expert Feasibility Analysis

Following feedback from material and media experts, Phase I revisions were made. Material experts clarified learning outcomes, added case studies, and provided project worksheets. Improvements were made to the quality of images in infographics for better readability. The volume of background sound was reduced, and a mute button was added to avoid interference with video playback.

A test was carried out on the media application with 10 students from class X at SMA Negeri 1 Kendal. The students downloaded the application, tried it out, and answered a questionnaire. The results of the questionnaire are presented in Table 1.

Table 1. Responses of Students

Aspect	Average Scores (%)	Cateories
Design of Application	87.19	Very Good
Benefits of Media	84.50	Good

Following feedback from students, the study found that there were areas for improvement in the educational materials. The recommended changes included improving button functions, adding background music, and reducing media file sizes. After addressing the feedback, the materials were improved with the addition of pause and playback buttons, better image quality and background music. During the trial, students were keen on using the learning app. They found it simple to use and useful in comprehending the materials, especially during the quiz section.

In the second revision, the quality of the images and fonts was improved for better readability, and additional buttons were added to view the original file linked to Google Drive. Extra buttons were added for viewing the source file on Google Drive and pause and playback buttons were also incorporated into the introductory video.

Effectiveness of PjBL-Physics Edu Media

1. t-Test Results

The Paired Sample t-test results for the experimental group indicate a significant value of 0.00. This suggests a disparity between pretest and posttest scores within the experimental group. Conversely, the Paired Sample t-test results for the control group exhibit a significant value of 0.609, exceeding 0.05 and indicating an absence of discrepancy between pretest and posttest scores within the control group. A test was conducted to see if there was a variation between the post-test outcomes of the control group and the experimental group. The SPSS output shows a significant value of 0.00 in the Equal Variances Assumed table, indicating a difference between the post-test results of the control and experimental groups, due to the evenness of the data. The SPSS output shows a significant value of 0.00 in the Equal Variances Assumed table, indicating a difference between the post-test results of the control and experimental groups, due to the evenness of the data.

2. The improvement of the 21st century skills

The development of 21st century skills was assessed through pretests and posttests carried out for each group. The experimental group showed an increment in the mean score from 47.58 to 70.40, while the control group increased from 52.82 to 66.93. Additionally, the results from the n-gain test revealed an enhancement in 21st century skills. The trial group showed an n-gain score of 0.46, signifying a moderate increase, compared to the control group's score of 0.29, indicating a low increase. The pretest and posttest scores for both groups are presented in Figure 5.

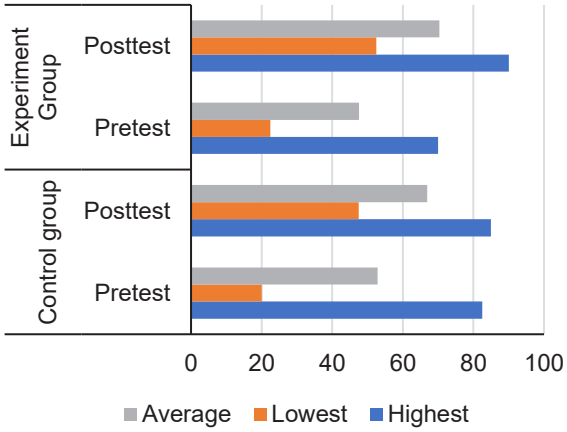

Figure 5. Student Pretest and Posttest Results

The student results have been split into three groups - high, moderate, and low. Each group has a comparable number of results. The grouping is based on the value order, from highest to lowest. The average value of each group is displayed in Table 2.

Table 2. Average Value of 21st Century Skills Knowledge in Each Group

	Group of Students	Pretest	Postest	*n-gain*
Control group	Upper group	67	77	0.28
	Middle group	55	68	0.30
	Lower group	38	65	0.29
Experimental group	Upper group	70	84	0.58
	Middle group	50	70	0.40
	Lower group	32	58	0.39

a) Results of Critical Thinking Skills in Problem Solving

Critical thinking skills are focused on the aspects of generating effective reasoning and the use of systems thinking. The results of critical thinking skills are displayed in Table 3.

Table 3. Critical Thinking Skills Scores

Scores	Control group	Experimental group	Score Difference	N-Gain
Highest	92	96	4	-
Lowest	46	67	21	-
Average	69	84	15	0.48

The n-Gain value of critical thinking skills of students between the control group and the experimental group in Table 3 shows 0.48, which is in the medium category. This contrast may be due to the fact that students in the second class are unfamiliar with problem-solving questions. Table 4 indicates the significance of the learners' critical thinking abilities in each dimension.

Table 4. Value of Students' Critical Thinking Skills in Each Aspect

Critical Thinking Aspects	Control Group	Experimental Group
Produce effective reasons	79	85
Using systems thinking	67	84

The research concentrates on implementing innovative and original ideas and working creatively with others, as displayed in Table 5. It focuses on applying creative thinking skills.

Table 5. Creativity and Innovation Skills Values

Scores	Control Group	Experiment Group	Score Difference	N-Gain
Highest	93	96	3	-
Lowest	46	54	8	-
Average	69	82	13	0.42

The improvement value of the students' innovation and creativity skills between the control group and the experimental group in the table is 0.42. The Table 4.5 displays that the students in the experimental group have improved their creativity and innovation skills with a N-gain score of 0.42 compared to the control group. Based on the N-gain value, we can say that there's a contrast in creativity and innovation abilities among the control and experimental groups in the medium range. The creativity and innovation skill values for each aspect are detailed in Table 6.

Table 6. Student Creativity and Innovation Skills Scores in Each Aspect

Aspects of Creativity and Innovation Skills	Control Group	Experimental Group
Using creative thinking in innovation	69	80
Work creatively with others	70	82

b) Communication Skills Results

This study focuses on three main aspects of communication skills: the role of the communicator, the role of the communicant, and the use of media as a communication tool. Table 7 displays the results of observing communication skills in both the experimental and control classes during the learning process.

Table 7. Communication Skills Score

Score	Control group	Experimental group	Score difference	Gain
Highest	91	97	6	-
Lowest	34	59	25	-
Average	69	82	13	0.42

The improvement in communication skills of students between the control group and experimental group is 0.42, as shown in Table 8. This figure indicates that there is a notable divergence in communication skills between both classes, falling under the medium category. Additionally, Table 8 displays communication skills scores for every aspect..

Table 8. Communication Skills Values for Each Aspect

Aspects of Communication Skills	Control group	Experimental group
Role as communicator	72	79
Role as communicant	67	79
Use of assistive media	70	78

c) Collaboration

The findings of studying how well the experimental and control groups work together can be found in Table 10. The gain value presented is 0.20. Table 9 demonstrates the collaboration scores for each aspect.

Table 9. Student Collaboration Skills Scores

Score	Control group	Experimental group	Score Difference	Gain
Highest	94	100	6	
Lowest	38	56	18	-
Average	75	80	5	0.20

According to the data analysis, it can be said that the collaborative abilities have improved between the test group and the control group. This variation is considered to be low.

Table 10. Value of Student Collaboration Skills in Each Aspect

Aspects of Collaboration Skills	Control group	Experimental group
Interact effectively with others	74	84
Work effectively in a diverse Team	72	76

b) ICTs Skills

The ICT abilities of the experimental and control groups are shown in Table 12. The gain value indicated is 0.19. Table 11 reveals the value of ICT aspects for each aspect.

Table 11. Nilai Keterampilan ICTs Siswa

Score	Control group	Experimental group	Score difference	Gain
Highest	88	94	6	-
Lowest	44	44	18	-
Average	68	74	6	0.19

According to the analysis, it can be said that there has been a rise in ICT abilities in the experimental class when compared to the control class. This variation falls under the low category.

Table 12. Student ICT Skills Scores in Each Aspect

Aspects of ICTs Skills	Control group	Experimental group
Ability to access and use Information	68	84
Analyze and apply technology	68	76

c) Life Skills & Career Skills Results

The findings from monitoring practical abilities and job-related skills in the experimental group and the control group are shown in Table 14. The recorded increase is 0.36. The data for each aspect of practical abilities and professional expertise are laid out in Table 13.

Table 13. Value of Life Skills & Career Skills

Score	Control group	Experimental group	Score difference	Gain
Highest	94	94	0	-
Lowest	38	56	18	-
Average	72	82	10	0.36

According to the data analysis, it's been found that the experimental group showed an increase in their Life & Career Skills in comparison to the control group. This variation falls under the moderate category.

Table 14. Student Live Skills & Career Skills Scores in Each Aspect

Aspects of Live Skills & Career Skills	Control group	Experimental group
F.4.1 develop character education	73	82
F.4.2 apply spiritual values	72	82

Discussion

PjBL-based digital learning media has been developed as a supplement and tool to assist teachers in online and offline learning activities. The objective of the materials is to be helpful companions to students in understanding the subject matter and enhancing character. It is envisaged that these materials will inspire teachers to explore more captivating and stimulating learning resources. "Enjoyable learning can help improve results and accomplish educational objectives (Sunarti, 2021).

The physics media app was made using SmartApp Creator (SAC)." desktop application that can be used to create Android and iOS-based mobile learning applications without using programming code. SAC can also produce apps in HTML5 and EXE formats. Smart Apps Creator can teach primary and secondary school students, as well as high school students, how to boost their creativity in managing content and creating captivating mobile applications (Rachman, 2019).

The app features video content on the global energy crisis, information about renewable energy, infographics on renewable energy sources in Indonesia, quizzes, reflective exercises, and references. The interface of application is displayed in Figure 6.

Figure 6. Display of the PjBL-Physics Edu application

The objective of producing this teaching material is to enhance the 21st century learning skilla of students. The evaluation process is divided into four categories: not standardized, nearly standard, standard, and outstanding, thereby simplifying the appraisal of 21st century learning skills. The study findings displayed that five out of the six dimensions of 21st century learning skills in the control group earned an average score of under 3, categorising them in the nearly control group. Only one area scored above 3 in the collaboration aspect. The control group incorporates group work

into their learning structure, which resulted in observed satisfactory collaborative abilities. The experimental group class met the standards, with an average score of more than 3 for each skill. ICT skills scored the highest score, followed by collaboration abilities. Using Android devices in the learning process can help students improve their ICT skills. Additionally, collaborative skills can be enhanced through project-based learning. To gain a better understanding of students of 21st century learning skills, refer to Figure 7.

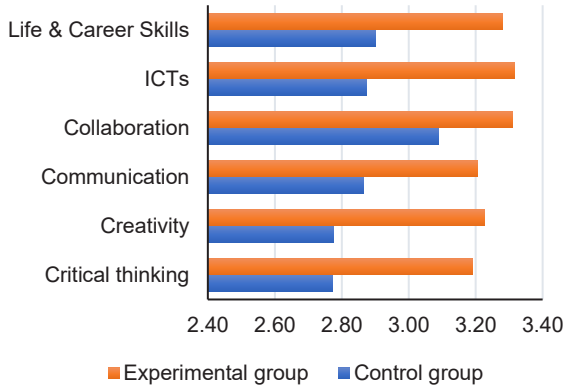

Figure 7. Student 21st Century Skills Profile

Based on the analysis of the data, it can be inferred that PjBL-Physics Edu media has the ability to enhance the learning skills related to the 21st century, falling under the category of moderate improvement. Additionally, this learning tool makes students more accustomed to technology, motivated, and engaged in the learning process. Therefore, it can be concluded that utilizing the PjBL-Physics Edu media app improves 21st century skills more effectively than employing the same method without digital media guidance. Nevertheless, the effectiveness of media cannot be confirmed based on the moderate n-gain score. The n-gain score in the medium category is likely influenced by differences in the mood of students and atmosphere when taking the test. Learning time in the experimental group takes place during the day, which reduces concentration of students.

Previous research by Mulyadi (2016) indicated that implementing the PjBL learning model could enhance student performance by 18.75%. This was achieved by improving student learning achievement from 15.70 in cycle 1 to 24.63 in cycle 2. The enhanced enthusiasm of students during meetings, where they discussed project designs and worked together on projects in groups, led to improved learning outcomes. Despite some students expressing a lack of understanding of the subject matter, their achievement results continued to rise. Kristanti (2016) found that students who participated in classroom activities using the PjBL approach met high standards. Additionally, student feedback on PjBL met the necessary criteria.

Similarly, Erlinawati (2019) conducted a study on using the STEM-focused PjBL approach, which is effective for teaching physics as it encourages student activity, creativity, ability exploration, and prepares students to compete in the age of technology. Maulana (2020) came to the same conclusion, stating that using the PjBL model effectively improves students' cognitive performance in physics. Improvements were also observed in the attitude domain's learning outcomes, achieving a high score.

In line with what was stated by Sari and Angreni (2018), PjBL is a learning process that directly involves students in the production of a project. Fundamentally, this learning method enhances problem-solving abilities when working on a project that yields a product. Through using projects as a learning method, this model allows students plenty of chances to choose a topic, research it, and finish a specific project. The students work as if they were in the real world and can create authentic products.

Maulidah's (2019) research shows that using the PjBL learning model can improve 4C skills. In addition, it positively impacts the enhancement of students' critical thinking skills. Moreover, Winangun (2021) highlighted that through PjBL and its scientific method, it is possible to establish a learning procedure that fosters 21st century skills such as critical thinking, communication, collaboration, and creativity. The PjBL learning method is a model that helps students to learn effectively. It helps to boost creative thinking of students through practical learning. By using this method, students are encouraged to explore the knowledge actively, ask questions, find

problems, and implement projects (Erdogan & Bozeman, 2015).

Through the PjBL learning model, Sudewi (2013) conducted research which revealed that students felt they could learn in a variety of ways. These included practicing critical thinking skills, working collaboratively in groups, developing solutions to societal issues, presenting their ideas and taking responsibility for their learning outcomes. Students also appreciated facing challenging learning tasks and learning from real-life experiences outside of textbooks, enabling them to think at a higher level and value group work. Furthermore, they learnt democratic principles, use scientific methodologies to solve problems, and participate in policy-making for the greater good of society. In addition, PjBL-based learning can enhance student performance, produce alterations in student performance and boost student learning accomplishment. Hence, PjBL-based learning is deemed effective for facilitating Independent Curriculum learning, which inspires students to attain 4C competencies (Mulyadi, 2016; Oktavianto, 2017). This implies that the PjBL approach, supported by physics edu media, can cultivate critical reasoning skills of students.

CONCLUSION

The results of this research are a learning medium in the form of an Android application to teach students about renewable energy materials, which can improve the 21st century learning skills of high school students. This media is designed with a project-based learning model, and it was found that the developed learning media is suitable for use in the classroom learning process with a moderate level of effectiveness. There was an increase in skills across the board, namely critical thinking, creativity and innovation, communication, collaboration, ICT and life and career skills.

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