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The Effectiveness of Tpack-Based Learning Physics with The PBL Model to Improve Students' Critical Thinking Skills

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Abstract

Critical thinking skills are thinking skills that are needed to live in the 21st century. This study aims to analyze the effectiveness of TPACK based physics learning with the PBL model to improve students' critical thinking skills. The research is a Pre-Experimental Design with the trial design a one-group pretest-posttest design. The subjects in this study were students of class X IPA 5 and X IPA 6 SMA Negeri 1 Driyorejo Gresik in the academic year 2020-2021. Trial design using. The data analysis technique used quantitative and interferential descriptive analysis. The results showed that physics learning based on TPACK with the PBL model was effective in improving students' critical thinking skills. In terms: a) improving critical thinking skills of students is significant at $\alpha = 0.05$ (2-tailed), b) mean n-gain score with high category, and c) nothing different in improving critical thinking skills of students at each class. Thus, TPACK-based physics learning with the PBL model can use as input for teachers to improve the critical thinking skills of students.

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INTRODUCTION

Education is an effort to improve the quality of human resources. Education is a structured and planned effort to realize the learning process without any age restrictions. The rapid development is accompanied by the development of technological science, which so far needs a response by the performance of the world of education that is professional and has high quality. The development of a country is influenced by educational activities because the future of a country is very much determined by how the country applies education (Yamin & Antasari, 2008).

There is an important component in the education system, namely the curriculum. This is because the curriculum does not only formulate the goals to be achieved but also clarifies the direction of education and provides an understanding of the learning experience that every student must have (Sanjaya, 2008). The curriculum is a set of plans and learning rules that include objectives, content, and teaching materials as well as methods that serve as guidelines for the implementation of the learning process to achieve educational goals (Kemendikbud, 2003).

Education in Indonesia has used various kinds of curricula, one of which is the 2013 curriculum. The 2013 curriculum is a curriculum that is capable of producing creative, productive, effective, innovative students, and integrated knowledge. The 2013 curriculum also requires students to have the ability to think at a higher level, work, be scientific, and communicate, especially in learning physics (Leonda, A. M., Desinta, & Budi, S. Agus, 2015). Physics has always been considered the most difficult and tedious subject by most students because there are too many formulas and numbers.

Physics is one part of Natural Sciences (IPA) which studies at the high school or vocational high school level that is studied natural phenomena or phenomena in the form of knowledge, ideas, and organized concepts through scientific activities (Widyaningsih, 2011). The process of physics learning does not only emphasize knowledge related to facts, concepts', and physics but provides direct experience to students so that students can understand the natural surroundings scientifically. In the 2013 curriculum, physics learning aims at high school to get religious values, be scientific, conduct experiments, communicate results, be able to increase mastery of concepts, principles, and skills in developing knowledge, a confident attitude as a complement to continuing education to a higher level, and able to develop science and technology (Kemendikbud, 2014). This is following the 21st-century competency framework which shows that knowledge is not enough only through the core subject, but is equipped with critical thinking skills (Partnership for Century 21st, 2009).

Critical thinking is a learning ability that is taught to students to understand a problem, seek information to solve problems, understand assumptions, formulate and make hypotheses, and draw conclusions that are by the problem (Ristontowi, 2011). Critical thinking is also an organized process and allows students to evaluate evidence, logic, and language that is the basis of student statements (Dewanti, 2011).

In the learning process, teachers play an important role in fostering the critical thinking skills of students. One of them is in the selection of models, content, and learning media that can support the learning process. Learning strategies that are considered to foster students' critical thinking skills are: 1) encouraging interaction between students and activities in groups; 2) provide open-ended questions that can open opportunities for students to answer confidently; 3) give students enough time to conclude answers; and 4) applying knowledge in everyday life (Potts, 1994). If the teacher can create a learning atmosphere that suits the individual or group needs, then these learning activities will run well.

According to Law No. 14 of 2005 on Teachers and Lecturers, it is stated that one of the duties of the teacher is to plan, implement, and assess and evaluate learning outcomes. To fulfill this task, teachers are required to be able to design a learning device for each material to be taught. One of the learning tools is the Learning Implementation Plan (RPP) and the teacher has made RPP before carrying out the learning process.

2020 is a tough year, where you have to stay at home, work from home, and school from home to support government programs to break the chain of spreading Coronavirus Disease - 19 (Covid- 19) which can kill anyone infected, not only in Indonesia but also throughout the world (Siahaan, 2020). Covid-19 has had a major impact on life, one of which is in the field of education. So that it brings changes to the

learning system, which previously face-to-face learning was implemented in schools, is now experiencing significant changes, namely being implemented online (in a network) or distance learning (Kemendikbud, 2020).

Online learning requires that all elements of education adapt to the online learning system, especially with the use of ICT. Problems that arise during online learning include internet access, learning facilities, parental understanding, and family finances. All of these obstacles play an important role in the success of online learning. Online learning is studying utilizes internet networks with accessibility, connectivity, flexibility, and the ability to open various types of interactions in studying. The successful implementation of online learning is support by several facilities such as smartphones, laptops, or the like that can access information anytime and anywhere (Gikas & Grant, 2013).

In online learning, teachers are expected to be able to innovate learning strategies by adapting to the lessons being taught. Teachers can use ICT to support the learning process online. One of the integrations of ICT in the online learning process is are developing TPACK-based learning tools, namely by combining Technology, Pedagogy, and Content Knowledge (Misra and Koehler, 2006). TPACK can act as a learning framework that functions to think about the knowledge a teacher has for integrating technology in the learning process and how to increase this knowledge.

In responding to the importance of students 'critical thinking skills but the unavailability of TPACK-based learning tools, innovative efforts are needed to assist teachers in developing TPACK-based learning tools to be able to improve students' critical thinking skills and make it easier for teachers to implement the online learning process. Besides, these efforts are also expected to be able to improve the quality of physics learning through the process of improving online learning.

Efforts that can be made in improving online learning include selecting and implementing physics learning by using a learning model that can provide students with opportunities to solve problems that exist in everyday life. This is following Sulardi's (2015) research which states that there is an increase in students' critical thinking skills with the Problem Based Learning (PBL) model. The PBL model is a learning model that has a huge influence on increasing the critical thinking skills of students in learning physics.

PBL is learning that uses real (authentic) problems in everyday life that are unstructured and open as a context for students to develop skills in solving problems and critical thinking and building new knowledge (Rusman, 2011). To get problems in learning the PBL model, you can summarize the news via YouTube, the internet, and television (Agustina, Kristiyanto, & Noviandini, 2017). PBL also requires students to focus on solving problems, be actively involved in the learning process can develop knowledge and thinking skills, both individually and in groups (Arifin, 2014).

One of the physics learning materials that allow students can see problems authentically is straight motion kinematics. The reason for choosing this material is because this material can be taught online learning and related phenomena encountered by students in everyday life. The PBL model is expected to be able to improve the critical thinking skills of students.

Based on the description above, to maximize the online learning process and improve students' critical thinking skills, it can be integrated into a TPACK-based learning tool. By integration technology in the form of a learning process using video conference applications such as google meetings, assignment collection via a google classroom, presence via a google form, E-modules in flipbooks, learning models using PBL, and straight motion kinematics materials are expected to make students discover related concepts. material, as well as studying indicators, can be achieved properly and optimally without misconceptions. So, the researcher designed and conducted a study entitled "The Effectiveness of TPACK-Based Learning Physics with the PBL Model to Improve Students' Critical Thinking Skills".

In general, the purpose of this study is to analyze the effectiveness of TPACK-based physics learning with the PBL model to improve students' critical thinking skills.

METHODS

This research is experimental. This research was conducted online (in-network). The subjects of this study were students of class X IPA SMA Negeri 1 Driyorejo Gresik in the odd semester of 2020/2021.

The population in this study were 36 students in class X IPA 5 and 36 students in class X IPA 6, SMA Negeri 1 Driyorejo Gresik.

Learning in this study was carried out using TPACK-based learning tools in the form of a syllabus, Learning Implementation Plan (RPP) using the PBL model, E-Module in the form of a flipbook, Student Worksheet (LKPD), test questions, PowerPoint (PPT), and assessment. This is structured to improve students' critical thinking skills by KD 3.4, namely analyzing physical quantities in straight motion with constant speed (fixed) and straight motion with constant acceleration and its application in everyday life such as traffic safety. Besides, is also equipped with supporting instruments, namely learning device validation sheets, lesson plan observation sheets, student response questionnaires, and critical thinking skills tests. The method in this study is Pre-Experimental Design research with a One Group Pretest - Posttest Design trial design (Prabowo, 2011). The design is described as follows:

$\mathbf{U_1 \rightarrow L \rightarrow U_2}$

With:

U_1: the initial test is to determine students' skills towards learning material before using treatment (pretest).

L: giving treatment to students, namely by carrying out a TPACK-based learning process with the PBL model to improve students' critical thinking skills.

U_2: the final test is to determine students' skills towards learning material after using treatment (posttest).

Data collection techniques are used to obtain relevant, accurate, and usable data by the objectives of the research being carried out. Data collection techniques used in this study are giving tests and response questionnaires. The analysis of the research results and the results of the learning trials in this study are as follows:

Analysis of the Validity of Learning Tools

Learning tools that include syllabus, lesson plans, E-Module, LKPD, test questions, PPT, and assessments that will be used are validated first by two validator lecturers to provide services to the validity of learning tools. In this study, the data collected were analyzed with an average score for each aspect with the following criteria:

Table 1. Criteria for Assessment of Learning Tools

Score	Information
$3{,}5 \leq X \leq 4{,}0$	Very Valid
$2{,}5 \leq X < 3{,}5$	Valid
$1{,}5 \leq X < 2{,}5$	Less Valid
$0 \leq X < 1{,}5$	Invalid

(Ratumanan & Laurens, 2006)

1) Analysis of Learning Implementation

Assessment of the implementation of learning is carried out by two observers at each face-to-face. The data were processed descriptively and quantitatively using the following equation:

$$P = \frac{the\ number\ of\ learning\ stages\ carried\ out}{the\ number\ of\ all\ stages\ of\ learning} \times 100\% \quad (1)$$

Then, the results of the implementation of learning are converted using the following assessment criteria:

3,50 – 4,00 = very good
3,00 – 3,49 = good
2,00 – 2,99 = good enough
1,00 – 1,99 = not good
(Riduwan, 2010)

2) Analysis of Students' Critical Thinking Skills

Skills tests are using to determine students 'mastery of students' critical thinking skills. Students' critical thinking skills were analyzed by description quantitatively. To determine students' learning completeness, the equation is:

$$P = \frac{total\ score\ obtained}{maximum\ score} \times 100\% \quad (2)$$

The results of students' critical thinking skills are declared complete if the value obtained meets the minimum completeness criteria (KKM) set by the school, which is 80.

From the data from the students 'pretest and posttest results, an n-gain analysis was carried out to show the differences in students' physics knowledge before and after the treatment.

$$\langle g \rangle = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \quad (3)$$

With:
<g> = gain score
S_{pre} = pretest score
S_{post} = posttest score
S_{max} = maximum score

Then the calculation results are converted with the following criteria:

Table 2. *n-gain* Criteria

Score	*n-gain* Criteria
0,7 < *n-gain*	High
0,3 ≤ *n-gain* ≤ 0,7	Medium
n-gain < 0,3	Low

(Hake, 1999)

Students' critical thinking skills after being given treatment using the TPACK-based PBL model, were carried out statistical analysis. The pretest and posttest difference tests were carried out in class X IPA 5 and X IPA 6 using parametric statistics with a significance level of α = 0.05 (2-tailed).

Differences in Students' Initial Critical Thinking Skills

To find out differences in students' initial understanding using the independent t-test on the pretest data with the following hypotheses:
H_0: there is no difference in the initial critical thinking skills of students in class X IPA 5 and X IPA 6.
H_1: there are differences in the initial critical thinking skills of students in class X IPA 5 and X IPA 6.
In testing the hypothesis, the criteria for rejecting or accepting H_0 based on t_{count} are as follows:
If $t_{count} > t_{table}$, then H_0 rejected
If $t_{count} < t_{table}$, then H_0 accepted
(Sugiyono, 2014).

Increasing Students' Critical Thinking Skills

To determine the increase in critical thinking skills of students for each class using the paired t-test on the pretest and posttest data with the following hypotheses:
H_0: there is no increase in students' critical thinking skills.
H_1: there is an increase in students' critical thinking skills.
In testing the hypothesis, the criteria for rejecting or accepting H_0 based on t_{count} are as follows:
If $t_{count} > t_{table}$, then H_0 rejected
If $t_{count} < t_{table}$, then H_0 accepted
(Sugiyono, 2014).

Differences in the Improvement of Students' Critical Thinking Skills

To find out the difference in the improvement of students' critical thinking skills using the independent t-test on the n-gain data with the following hypothesis:
H_0: there is no difference in the increase in the critical thinking skills of students in class X IPA 5 and X IPA 6.
H_1: there are differences in the increase in the critical thinking skills of students in class X IPA 5 and X IPA 6.
In testing the hypothesis, the criteria for rejecting or accepting H_0 based on t_{count} are as follows:
If $t_{count} > t_{table}$, then H_0 rejected
If $t_{count} < t_{table}$, then H_0 accepted
(Sugiyono, 2014).

RESULT AND DISCUSSION

Before carrying out the learning process, the learning tools used validated by two validator lecturers. The results of the validity of the TPACK-based physics learning device with the PBL model used have been declared valid and can be used in physics learning to improve students' critical thinking skills.

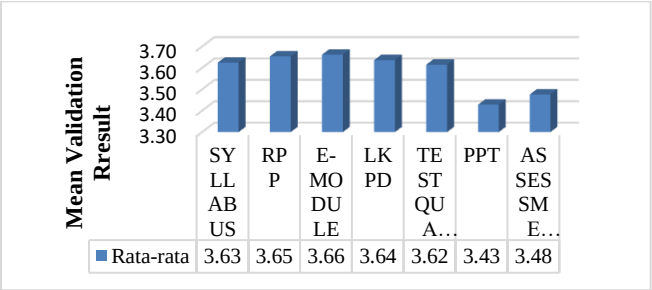

Figure 1. Validation Results of Physics Learning Devices

TPACK-based physics learning with the PBL model can be said to be effective if the learning process has been carried out well. Based on the analysis of the implementation of the lesson plan, it was found that

the phases of learning activities contained in the lesson plans for class X IPA 5 and X IPA 6 were carried out with an average score of 3.50 and 3.52 in both categories with the reliability of 93.33%.

Table 3. RPP Implementation Score

Component	X IPA 5		X IPA 6	
	Meeting 1	Meeting 2	Meeting 1	Meeting 2
Opening Activities	3,17	3,83	3,33	4,00
Core Activities	3,07	3,43	2,93	3,43
Closing Activities	3,25	4,00	3,25	4,00
Time Management	4,00	4,00	4,00	4,00
Class Situation	2,75	3,50	2,75	3,50

The mean score for lesson plans for class X IPA 5 and X IPA 6 includes opening activities, core activities, closing activities, and time management is a good category. The class situation in learning was not optimal at the first meeting. because students feel not used to virtual learning via google meetings, so it takes quite a long time to adapt to the learning process.

Good implementation of lesson plans shows that teachers can manage learning according to phases of the TPACK-based PBL model. The teacher can guide students into PBL learning situations so that students can find concepts from problems in everyday life related to straight motion kinematics material correctly. This is by Vigotsky's Scaffolding theory regarding the concept of assisted learning, which states that the teacher is a guide in the learning process so that students can master the material thoroughly and can develop cognitive skills to a higher level (Nur, 2011). This theory is also supported by Bruner (Nur, 2011), who states that teachers do not only think about teaching but how to guide students to learn more optimally so that students can master the concepts of physics by predetermined learning objectives.

Before carrying out the learning process by implementing TPACK-based learning with the PBL model, students a pretest to determine the students' initial skills. After carrying out the learning process, students a final test (posttest) to determine the students' final skills. The pretest and posttest scores are used to measure the differences in student learning outcomes between before and after carrying out TPACK-based learning with the PBL model to improve students' critical thinking skills in straight motion kinematics material. This value is then analyzed descriptively and followed by the calculation of n-gain to determine the increase in the results of students' critical thinking skills.

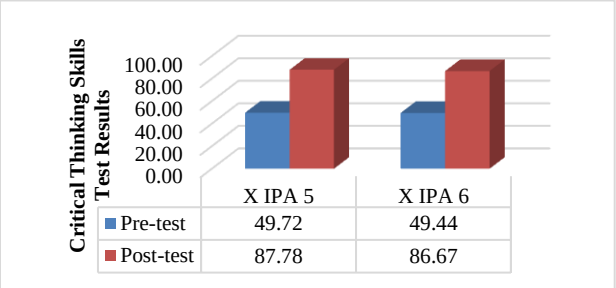

Figure 2. The Mean Result of the Critical Thinking Skills Test of Class X IPA 5 and X IPA 6 Students

Based on the descriptive analysis, it is found that before was carried out TPACK-based learning with the PBL model, students' critical thinking skills were below the KKM with the mean pretest scores of class X IPA 5 and X IPA 6 being 49.72 and 49.44. After students carried out the PBL-based TPACK-based learning process, the average critical thinking skills test score of students increased with posttest scores from class X IPA 5 and X IPA 6 of 87.78 and 86.67 with the total number of students who completed overall as many as 64 people and as many as 8 people who have not completed.

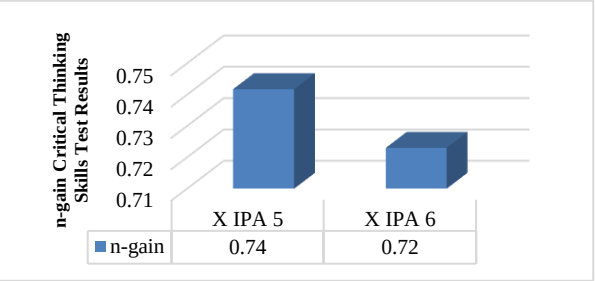

Figure 3. Hasil Rata-rata *n-gain* pada Kelas X IPA 5 dan X IPA 6

Differences in Students' Initial Critical Thinking Skills

The test for differences in students' initial critical thinking skills used the pretest data for critical thinking skills using the independent t-test with a significance level of $\alpha = 0.05$ (2-tailed).

Table 4. Independent t-test results on the pretest data

Sample	Mean	Std. Deviation	t_{count}	t_{table}	Information
X IPA 5	49,722	157,064	0,097	2,030	H_0 accepted
X IPA	49,444	136,853			

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In the table above, it can be seen that the value of $t_{count} < t_{table}$, the meaning is no difference in initial critical thinking skills between students in class X IPA 5 and class X IPA 6 before doing TPACK-based learning with the PBL model.

Improvement of Students' Critical Thinking Skills

The test for increasing students 'critical thinking skills used to pretest and posttest data for students' critical thinking skills using the paired t-test with a significance level of $\alpha = 0.05$ (2-tailed).

Table 5. Paired t-test result on the pretest and posttest data

Sample		Mean	Variance	Pearson Correlation	t_{count}	t_{table}	Information
X IPA 5	*pret*	49,7	157,0	0,006	14,71	2,030	H_0 rejected
	est	22	64				
	post	87,7	80,63				
	est	78	5				
X IPA 6	*pret*	49,4	136,8	0,028	13,834		
	est	44	25				
	post	86,6	131,4				
	est	67	29				

In the table above, it can be seen that the value of $t_{count} < t_{table}$, the meaning is an increase in students' critical thinking skills after TPACK-based learning with the PBL model is carried out.

Differences in the Improvement of Students' Critical Thinking Skills

The difference test for the improvement of students' critical thinking skills using the n-gain data for critical thinking skills using the independent t-test with a significance level of $\alpha = 0.05$ (2-tailed).

Table 6. Independent t-test results on the n-gain data

Sample	Mean	Std. Deviation	t_{count}	t_{table}	Information
X IPA 5	0,742	0,044	0,358	2,030	H_0 accepted
X IPA 6	0,723	0,055			

In the table above, it can be seen that the value of $t_{count} < t_{table}$, the meaning is no difference in the improvement of critical thinking skills between class X IPA 5 and class X IPA 6.

Based on the skills test before and after the learning process, there was a significant increase in the critical thinking skills of students. Increasing the skills of students can be seen from the calculation of the n-gain pretest and posttest students. The results calculations obtained the mean n-gain of each class X IPA 5 and X IPA 6 amounted to 0.74 and 0.72 with a high category. It shows that TPACK-based learning with the PBL model is applied in the learning process on straight motion kinematics material can significantly improve students' critical thinking skills. The results of this study support the research conducted by Sulardi (2015) regarding the development of PBL model physics learning tools to train students 'critical thinking skills, which shows that the PBL model can train students' critical thinking skills.

The learning process with the PBL model is supported by Vygotsky's theory, which emphasizes the principle of the zone of proximal development (Arends, 2013). The teacher uses Vygotsky's theory in learning physics by determining tasks that go beyond the skills of students with a teacher of guidance. The initial steps of learners depend on the teacher, then learners become more independent after mastering the task of learning and gain new understanding. Teachers are required to become facilitators of students to master new learning skills and experiences (Khotimah in Ayuningtyas, 2015).

In the physics learning process, students who act as learning subjects need to be guided and trained gradually in developing their thinking skills. One is the critical thinking skills through a series of problem-based learning learners are expected to think reflectively, logically, and systematically (Hidayah et al, 2017). The topic used in improving critical thinking skills is straight motion kinematics.

The results of interferential statistical analysis to analyze the effectiveness of TPACK-based physics learning with the PBL model to improve students' critical thinking skills. The data obtained were then analyzed statistically using parametric interference statistical analysis (independent t-test and paired t-test).

Students' initial critical thinking skills analyze from the pretest data for critical thinking skills on the t-independent test with a significance level of $\alpha = 0.05$ (2-tailed). In class X IPA 5 and class X IPA 6 have $t_{count} < t_{table}$, which means there is no difference in initial critical thinking skills in each class. This shows that

students have the same critical thinking skills before carrying out the TPACK-based learning process with the PBL model.

Improved critical thinking skills of students analyzed data from the pretest and posttest critical thinking skills of each class (X X IPA IPA 5 and 6) using a paired t-test with significance level $\alpha = 0.05$ (2-tailed). In class X IPA 5 and X IPA 6 have $t_{count} > t_{table}$, this means that there is a significant increase in students' critical thinking skills in straight motion kinematics material after carrying out TPACK-based learning with the PBL model.

The results of different tests for improvement of students' critical thinking skills after learning using n-gain critical thinking skills for each class used the independent t-test with a significance level of $\alpha = 0.05$ (2-tailed). In class X IPA 5 and X IPA 6 have $t_{count} < t_{table}$, this means that there is no difference in the improvement of student's critical thinking skills in each class.

Results of the independent t-test are used to determine differences in the significant increase in the critical thinking skills of students in class X IPA 5 and class X IPA 6. The results obtained show that is no significant difference between an increase in the critical thinking skills of students in class X IPA 5 and X IPA 6. This can happen because the teacher has implemented TPACK-based learning with the PBL model optimally.

The critical thinking skills achieved by students of class X IPA 5 and X IPA 6 are in good categories with an average score of 85.73. These results can be achieved because students continue to practice for two meetings to carry out the learning process. At the first meeting, the teacher simulates how to experiment so that students have an idea of the experiment to be carried out. Furthermore, students conduct experiments with teacher guidance in designing experiments, taking data, analyzing, and making conclusions critically and logically. Although the students have not been accustomed to a test of skill, to make learners feel alienated when designing experiments, retrieving, and analyzing, but the students are so happy in the implementation of the learning process that can improve critical thinking skills that are arrange based learning TPACK model PBL.

Based on the results of skills test completeness, students have been able to practice critical thinking skills through skills tests. However, students still need ongoing guidance and training with the aim that students are accustomed to using critical thinking skills in solving problems in everyday life, especially in physics concepts and the results achieved are more optimal.

Based on the results of statistical analysis interferential, it can conclude that TPACK-based learning with PBL model can demonstrate the effectiveness value to improve the critical thinking skills of students during the studying online, this is according to research conducted by Titin Mairisiska (2014) concerning the development of devices based learning TPACK in the material of the colligative nature of the solution to improve students 'critical thinking skills which shows that TPACK-based learning tools can optimize learning and can improve students' critical thinking skills.

The implementation of critical thinking skills in the physics learning process has been arranged with strategies and methods following the online learning process, with the hope of meeting the 2013 curriculum achievement targets which state that is an increase and balance between the skills and knowledge of students which include cognitive, affective, and psychomotor. Thus, physics learning based on TPACK with the PBL model can use as input for teachers to improve students' critical thinking skills. Technologies that can use to support online learning include video conference applications for face-to-face learning so that students can learn optimally even though only online because students are more interested and enthusiastic about using video conferencing applications than using only WhatsApp and google classroom.

CONCLUSION

Based on the results of data analysis, can be concluded that physics learning based on TPACK with the PBL model is the effectiveness in improving the critical thinking skills of students of SMA Negeri 1 Driyorejo Gresik. in term from the increase in critical thinking skills scores of students significantly, the mean n-gain score is high, and there is no difference increase of critical thinking skills between students in class X IPA 5 and X IPA 6 SMA Negeri 1 Driyorejo Gresik.

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