Physics learning by PhET simulation-assisted using problem based learning (PBL) model to improve students' critical thinking skills in work and energy chapters in MAN 3 Sleman

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Abstract

This research aims were to: (1) produce a PhET simulation-based learning device that who being used in physics learning activities by using Problem Based Learning (PBL) model to improve critical thinking skills of students MAN 3 Sleman in chapter work and energy, (2) knowing the effectiveness of learning medium in the form of PhET simulation in physics learning activity using PBL model, and (3) knowing the improvement of critical thinking skills of students in MAN 3 Sleman. This research is a development research with 4D model. The define stage, defines the problem. The design stage, developing physics-based learning device PhET simulation using PBL

model. The development stage, resulting in PhET simulation based physics learning device using the revised PBL model. The disseminate stage, the dissemination of PhET simulation based physics learning device using PBL model. The research results, (1) The PhET simulation based physics learning device using PBL model feasible use in physics learning activity. This is evidenced from the acquisition of Aiken's V validity score through validation result, students's response result, and valid and reliable assessor approval level, (2) Learning medium in the form of PhET simulation is effectively used in physics learning activities. This is evidenced by the sig value. of 0.00 in the modeling class and implementation class, meaning the PhET simulation application allows students to improve their critical thinking skills, and (3) Improvement of critical thinking skills of students MAN 3 Sleman in modeling class and implementation class that are 23.84% and 41.90% respectively with value of standard gain of 0.35 and 0.61 which are included in medium category.

Keywords: Learning device development, PhET, problem based learning, critical thinking skills, work and energy.

Introduction

In the implementation of educational activities in schools there are often challenges that come from within and from outside, one of which demands advances in technology that must be followed by the positive side and left the negative side. The challenges that arise from the development of human life become a separate requirement for a teacher to adapt his learning to existing demands (Davis, 2013). In line with this explanation, Purbasari et al. (2013) stated that technological advances in the world of education are currently developing rapidly with the large use of smartphones by students in learning activities. This is consistent with the data obtained by Agusta and Djukri (2015) that the use of smartphone types of smartphones by students in MAN 3 Sleman, Yogyakarta is 52.35%. However, the use of smartphones by these students has not been able to have a positive impact in achieving the desired learning goals (Manumpil et al., 2015).

Most students abuse the use of smartphones in classroom learning such as just playing games, watching videos, and even exchanging messages with friends or others (Anita, 2013). In line with this, Fatimah and Mufti (2014) stated that students tend not to realize that the use of smartphones in learning activities can also facilitate them in understanding chapter taught by teachers, one of them through various

android-based learning applications. Furthermore, Astra et al. (2015) and Dwijananti and Hadi (2016) stated that learning medium in the form of physics laboratories and physics comics based on android are suitable for learning medium for high school students. Wardani et al. (2017) also proved that android-based physics games can improve student learning outcomes and critical thinking skills.

However, technological advances in education must also be integrated into the current physics subject curriculum, especially in Indonesia, i.e the 2013 Curriculum. In the 2013 curriculum, learning material is explaned to students using a scientific approach, where students are trained to observe problems, analyze, solve, and communicate them in writing and orally with the assisted of existing technology (Hosnan, 2014: 34). In addition, students are also required to be skilled in various things, such as reasoning, processing, and presenting data or solutions to problems that are critical, creative, effective, collaborative, communicative, and solutive (Minister of Education of the Indonesia Republic No. 21 of 2016). Physics has an important role in advancing education in Indonesia, thus attracting educators to carry out physics education in a planned manner based on existing physics concepts that are integrated with phenomena or events that occur in the surrounding life. However, in the implementation of physics education in schools it would be better, if the physics chapter taught by the teacher to students is packaged using practical technological assistance and connecting physics chapter with phenomena in everyday life (Suastra et al., 2017). In line with this finding, Luangrath et al. (2011) found that the results of assessment of students' conceptual understanding and critical thinking in the mechanics chapter combined with events or experiences from daily life were higher than textually.

Physics learning with the assisted of technology and applying it to phenomena in daily life will be better if it is adjusted to the learning guidelines or curriculum in schools, one of the 2013 Curriculum (Kuswandari, 2013). Learning in the 2013 Curriculum uses a student-centered learning approach, where students are asked to find out information independently and the teacher is only a facilitator (Megawarni, 2015). Therefore, in this revised 2013 curriculum, it is recommended that learning models used in learning activities are inquiry models, project-based learning models, and problem-based learning models because they are in accordance with scientific approaches and train students' critical thinking skills (Shoimin, 2014). Learning resources used by students in physics learning activities do not only come from the

teacher, but can be from anywhere related to physics chapter. With the variety of learning resources used by students in learning a physics chapter, students are expected to be able to understand physics chapter and be able to find problems with solution solutions related to physics chapter in everyday life (Suwandi et al., 2016). Problems related to physics in daily life must have multidimensional answers, so that they can be solved in various ways (Rudyanto, 2014).

Meanwhile, through observation activities at school found problems such as the lack of innovative learning medium used by teachers in explaning physics chapter to students, so students are not enthusiastic about the material explaned by the teacher. Teachers are only fixated on using learning medium that is only provided by schools, they do not collaborate with students to develop their own simple physics learning medium in accordance with technological advancements (Chai et al., 2017; DeFauw, 2018). In addition, another problem found in learning physics at school is the tendency of teachers to explanation physics learning materials just being centered on the teacher. One reason that is often expressed by teachers is why they often use the discourse method to explanation physics chapter to students, because they think the discourse method can accelerate the explanation of physics chapter to students rather than other methods or models that are student-centered (Moradi et al., 2018). Therefore, the impact that often occurs in students with physics learning methods like that is a variety of important abilities that must be mastered by students can not be mastered optimally, such as the ability to understand concepts, critical thinking skills, and creative thinking abilities (Lince, 2016). In addition, students also cannot optimize their confidence, curiosity, and communication skills in public if physics learning activities still use teacher-centered methods (Sari et al., 2019).

Actually, there have been many physics learning medium that have used technology, both in the form of an android simulation medium (PhET), physics learning videos, or online physics comics. However, from a variety of physics learning medium that applies the easiest and cheapest use of the technology to be used in high schools in Indonesia by teachers and also students is to use an Android-based simulation medium such as PhET (Yusuf, & Widyaningsih, 2019). The reason is very logical because more than 52.35% of students use smartphones and of course teachers must also have used smartphones too (Nagel, 2018). In addition, the PhET simulation is a physics learning simulation medium that has been provided by developers on the internet and we just simply download and use it on a smartphone or laptop in

accordance with the physics chapter that we are going to study (Nurahman et al., 2019). This medium is offline or does not use internet signals in its use, so this medium is very cheap and easy and can be used anywhere and anytime. With the PhET simulation in learning physics, students can learn physics independently and actively centered on themselves and the teacher only as a facilitator (Bo et al., 2018). This PhET simulation also supports student-centered physics learning activities carried out by the discussion method with various learning models that require active students (Roll et al., 2018).

Meanwhile, there have been many physics learning that uses a variety of methods and models that are student-centered, one of which is the question-and-answer discussion method with PBL models. The problem based learning (PBL) model is one of the student-centered learning models, by combining problems that occur in everyday life with physics concepts and students are asked to solve these problems with critical thinking (Wijnia et al., 2019). The application of PBL models in physics learning will be more optimal, if physics problems can be integrated with instructional medium that students can directly use either individually or in groups (Darma et al., 2018). Therefore, one of the learning medium that supports the PBL model is the PhET simulation medium, because this medium can be used directly by each student in the group to assist find solutions to solving everyday problems with the concept of physics (Umarella et al., 2019).

Meanwhile, Hayati et al. (2013) suggested that the teaching-learning process that uses the PBL model can familiarize students in implementing the scientific method by providing students with independent opportunities to improve their critical thinking. Students who use the PBL model in their learning activities, then in their learning activities are much better because they actively participate in learning activities (Siwa & Muderawan, 2013). Furthermore, Astutik and Prahani (2018) states that learning physics assisted with android simulations can improve students' creative and critical thinking skills. Moreover, physics learning especially in chapter related to mechanics, is combined with PhET simulations and PBL models, students will be more active in learning and their critical and creative thinking skills will increase. Furthermore, Sugiarto and Djukri (2015) argues that PBL model with android simulation is able to assist in increasing students' critical thinking in overcoming environmental problems. As is done by Czabanowska et al. (2012), that the implementation of learning activities that use PBL learning model can develop

students' thinking skills through information processing, critical thinking, and instill in the students themselves to be responsible. Meanwhile, Tan (2014) also mentioned that PBL has been recognized as a development of active learning centered on students, using unstructured problems (real-world problems or everyday life) as a basis in the learning process.

Meanwhile, the physics chapter used in this chapter is physics in the scope of mechanics, i.e work and energy. This chapter is adapted to the results of research which states that work and energy is one of the chapter in physics that is misconceptions still occur and is one of the physics chapters that is not easy (Kubsch et al., 2017). In addition, the concept of work and energy is included in the concept whose phenomenon tends to be abstract because this concept cannot be observed with the naked eye (Zhang et al., 2019). Meanwhile, a study was conducted by Ivowi who examined misconceptions in physics from 128 students from two high schools in Nigeria (Graham & Berry, 1996). He asked students to explain clearly about energy conservation and about half of the sample gave incorrect answers to energy conservation questions (Graham & Berry, 1996). In the study, Ivowi revealed that (although the concept of energy is related to mass and speed) students associate energy conservation erroneously only with the concept of speed.

Furthermore, Singh and Rosengrant investigated students' understanding of the concepts of energy and work, obtained the result that most students had difficulty interpreting conceptually the basic principles relating to energy and work (Singh & Rosengrant, 2003). In addition, the taking of this material is also adapted to the syntax in the PBL model, so that this is expected to occur during the learning process. Thus, the objectives to be achieved in this study are to produce a PhET simulation-based learning device that is being used in physics learning activities by using Problem Based Learning (PBL) models, knowing the effectiveness of learning medium in the form of PhET simulation in physics learning activity using PBL models, and knowing the improvement of critical thinking skills of students in MAN 3 Sleman. In addition, the existence of this research is expected to be a reference and guide to physics research in future studies.

Materials and Methods

Research participants

This research was conducted in MAN 3 Sleman. MAN 3 Sleman is a high school based on Islam in the Special Region of Yogyakarta, Indonesia. MAN itself stands for Madrasah Aliyah Negeri which is an Islamic religion-based high school in Indonesia. Madrasah Aliyah Negeri is an Islamic-based high school that is under the authority of the Indonesian Ministry of Religion. In addition, students and teachers who are in the MAN environment, especially MAN 3 Sleman are all Muslim and dressed in the Islamic order. In its learning, MAN 3 Sleman students obtain subject matter as is the case with middle school students in general, but are given additional kinds of Islamic religious subject matter. This research was conducted at MAN 3 Sleman in the even semester of academic year 2018/2019 from February-May 2018. In addition, the subjects of the study were the students of class X MIPA at MAN 3 Sleman. MIPA itself is an abbreviation of mathematics and natural science, where the abbreviation is often used in Indonesia. The 10th grade students of MIPA at MAN 3 Sleman are students who are at the second level in Islamic-based high schools with their departments are mathematics and natural sciences. In this study, the class used amounted to two class. The number of students in each class is different, in class X MIPA 1 there are 32 students and class X MIPA 3 has 30 students. Class X MIPA 1 is a modeling class and class X MIPA 3 as an implementation class.

Research Stages

Meanwhile, this research method used in this research is Research and Development (R & D) research method. Sugiyono (2015: 407) states, research methods R & D is a research method used to produce a specific product and test the feasibility of the product. Because of this research using research development or R & D method, the research design used in this research is adapted from 4D model by Thiagarajan et al. (1974). Design research with 4D model consists of 4 main stages: Define (definition); Design (design); Develop (development); and Disseminate (spread).

The define phase aims to define various kinds of problems that occur in physics learning, especially in MAN 3 Sleman and define, also design ways to solve various problems in physics learning activities. In this define phase consists of four main steps carried out in this study as follows. (i) The preliminary analysis; the purpose of the preliminary analysis is to determine the main problems faced in learning physics

in high schools, especially in MAN 3 Sleman. Preliminary analysis activities were carried out by observing physics learning activities of class X MIPA in MAN 3 Sleman, interviewing physics teachers in class X MIPA at MAN 3 Sleman, and observing the situations and conditions when physics learning was taking place at MAN 3 Sleman. (ii) The analysis of students; the analysis of students was conducted with the aim to determine the characteristics of class X students at MAN 3 Sleman such as age, academic skills, motivation to learn, levels of cognitive development, and students' critical thinking skills. Meanwhile, the technique of determining the sample as the subject of this study uses a purposive sampling method. Marshall and Rossman (2014) state that the purposive sampling method is a technique or method of taking research subjects that are not based on level and random, but are based on the existence of certain objectives. Students in two classes of X MIPA in MAN 3 Sleman were selected as research samples based on the learning outcomes obtained and the frequency of using smartphones in learning physics. Thus, the characteristics of class X MIPA students at MAN 3 Sleman can be known through observing the behavior displayed by them when they are in class or outside the classroom and also through interviews with physics teachers of class X MIPA at MAN 3 Sleman.

(iii) Curriculum analysis; the purpose of the curriculum analysis phase is to determine and describe physics chapters, especially work and energy chapter in class X physics learning activities that refer to the core competencies and basic Competencies in accordance with the revised 2013 curriculum in MAN 3 Sleman. The curriculum analysis phase is carried out by determining indicators of achievement of competencies and learning objectives in accordance with the basic competencies selected based on the PhET simulation using the problem based learning (PBL) model class X MIPA at MAN 3 Sleman for the work and energy chapter. The selection of work and energy chapter is based on the results of observations and interviews with students and physics teachers of class X MIPA in MAN 3 Sleman which shows that the physics learning outcomes of class X MIPA students from year to year on work and energy materials are lower than the learning outcomes of physics chapters other. In addition, students also find it difficult to understand work and energy material, because energy chapter is abstract so misconceptions often occur on students. The level of misconception of students of class X MIPA in MAN 3 Sleman on work and energy chapter occupies the highest level than the misconception of other physics chapters. (iv) Conceptual Analysis; conceptual analysis is carried out by identifying the basic concepts of the physics

chapter on work and energy, with the aim of conveying the material to students systematically, organizing and detailing the concepts of the work and energy chapter, and connecting one concept with another concept to form a concept map related to the work and energy chapter. Meanwhile, the basis for choosing work and energy materials over other physics chapters has been discussed in the curriculum analysis section and in the previous section.

The design phase aims to develop solutions to problem solving in class X MIPA physics learning activities at MAN 3 Sleman identified through observation and interview activities with students and physics class X MIPA students at MAN 3 Sleman. The development of problem solving solutions in physics learning activities is in the form of the development of research instruments and the initial design of learning devices based on PhET simulations using PBL models. This design phase consists of three main steps as follows. (i) Development of research instruments; the development of this research instrument was carried out to develop a research instrument in the form of a physics learning device based on a PhET simulation using a PBL model that aims to solve problems in physics learning activities in class X MIPA in MAN 3 Sleman. (ii) Determination of learning devices type; the learning devices used in research activities at MAN 3 Sleman include the syllabus of the revised 2013 curriculum, which consists of two meetings each for 2 lesson hours and lesson plan (RPP). In addition, the learning device used is the PhET simulation developed by the physics department, University of Colorado. The PhET simulation, developed by the physics department, University of Colorado, is used as a learning medium and also as a medium for solving physics problems about work and energy on student worksheets (LKPD).

The developed LKPD applies several syntaxes from the PBL model. In addition, this study also developed pretest and posttest questions aimed at measuring students' critical thinking skills. These pretest and posttest questions were developed based on cognitive aspects of C4 (analyzing) and C6 (creating) in the revised Bloom taxonomy. These pretest and posttest questions each amount to 5 items open ended questions or description questions that require answers from students to a physics problem in accordance with the work and energy chapter. (iii) Selection of learning medium; the selection of learning medium used in this research activity is done by adjusting the learning devices used during the implementation of research activities. The selection of instructional medium in this study is based on the results of observations and

interviews with students and physics teachers at MAN 3 Sleman, where learning medium that are often used by teachers in explaning physics learning materials are using printed books and presentation of physics chapters using Ms. power point. The use of android simulation medium in the form of PhET has never been used by physics teachers at MAN 3 Sleman in supporting the explanation of physics learning materials to their students. In addition, the reason for choosing PhET simulation medium over other medium is because this medium has supported the achievement of the 4.0 industrial revolution in the field of education and this PhET simulation medium is also a simple offline medium in its use. Furthermore, the learning medium chosen in the research activities at MAN 3 Sleman that supports students in operating the PhET simulation include, laptops, android smartphones and LCD projector screens, and video game skate boards.

The development phase is carried out with the aim of producing PBL learning devices based on PhET simulations to improve the critical thinking skills of class X students in MAN 3 Sleman which are valid and reliable. This learning device was developed based on the results of validation and revision results in accordance with comments, suggestions, and expert validators and validation practitioners. In general, the development stage is carried out with the aim of obtaining comments and suggestions for improvement from the validator of experts and practitioners to the design of learning devices that have been developed at the design stage. This development phase consists of four main steps, as follows. (i) Expert and practitioner validation; this stage aims to validate the initial design of PhET simulation based learning devices by using PBL models to improve the critical thinking skills of class X students at MAN 3 Sleman by expert validators and practitioners through a validation questionnaire. Validator experts and practitioners who validate the learning device each amounted to one person. In general, aspects validated by expert and practitioner validators are aspects of the completeness of learning devices, presentation or appearance, physical material, and linguistic aspects.

The questionnaire used by expert and practitioner validators is in the form of a questionnaire asking them to choose the appropriate answer to the learning devices that have been developed. (ii) Revision; the revision stage is conducted with the aim of producing products based on inputs, suggestions, and improvements provided by expert and practitioner validators through validation activities. Furthermore, it produces a PBL-based simulated learning PBL-based learning device to improve the

critical thinking skills of students who are revised and ready for use in the coding class and implementation class. (iii) Implementation in the modeling class, implementation of modeling activities by applying learning device PBL-based PhET simulation to improve the critical thinking skills of students who were revised done in class X MIPA 1 with students amounted to 32 students. This activity was conducted to find out the work result of LKPD PBL based on PhET simulation, PhET simulation effectiveness, and improvement of critical thinking skill aspect in modeling class. (iv) Implementation in implementation class; implementation of implementation activities by applying learning device PBL-based PhET simulation to improve the critical thinking skills of students who were revised done in class X MIPA 3 with students amounted to 30. This activity was conducted to find out the work result of LKPD PBL based on PhET simulation, PhET simulation effectiveness, and improvement of critical thinking skill aspect in implementation class.

This disseminate phase aims to disseminate learning device PBL-based PhET simulation to improve aspects of critical thinking skills of students, such as other classes, other teachers, other schools, or published in scientific journals. Meanwhile, the instruments used in this study consisted of two types, i.e learning instruments and data collection instruments. The learning instrument used in this study was in the form of a syllabus of physics class X in the PhET-based work and energy chapter, PBL lesson plans (RPP) based on PhET simulations, PhET simulations, and PBL student worksheets based on PhET simulations. Details and descriptions of the learning instruments used in this study are as follows. (i) Physics syllabus of class X based on PhET simulation; the syllabus used in this study is a physics syllabus for the class X MIPA in MAN 3 Sleman which was prepared in accordance with the 2016 Minister of Education of the Indonesia Republic and the revised 2013 curriculum, but there are some modifications in learning activities using PBL models based on PhET simulations. The physics syllabus of class X based on PhET simulation developed in this study can be shown in Figure 1 below.

SILABUS MATA PELAJARAN FISIKA KELAS X

Satuan Pendidikan : MAN 3 Sleman
Mata Pelajaran : Fisika
Kelas/Semester : X / 2 (dua)

Kompetensi Inti

KI. 3 Memahami, menerapkan, dan menganalisis pengetahuan faktual, konseptual, prosedural, dan metakognitif berdasarkan rasa ingin tahunya tentang ilmu pengetahuan, teknologi, seni, budaya, dan humaniora dengan wawasan kemanusiaan, kebangsaan, kenegaraan, dan peradaban terkait penyebab fenomena dan kejadian, serta menerapkan pengetahuan prosedural pada bidang kajian yang spesifik sesuai dengan bakat dan minatnya untuk memecahkan masalah.

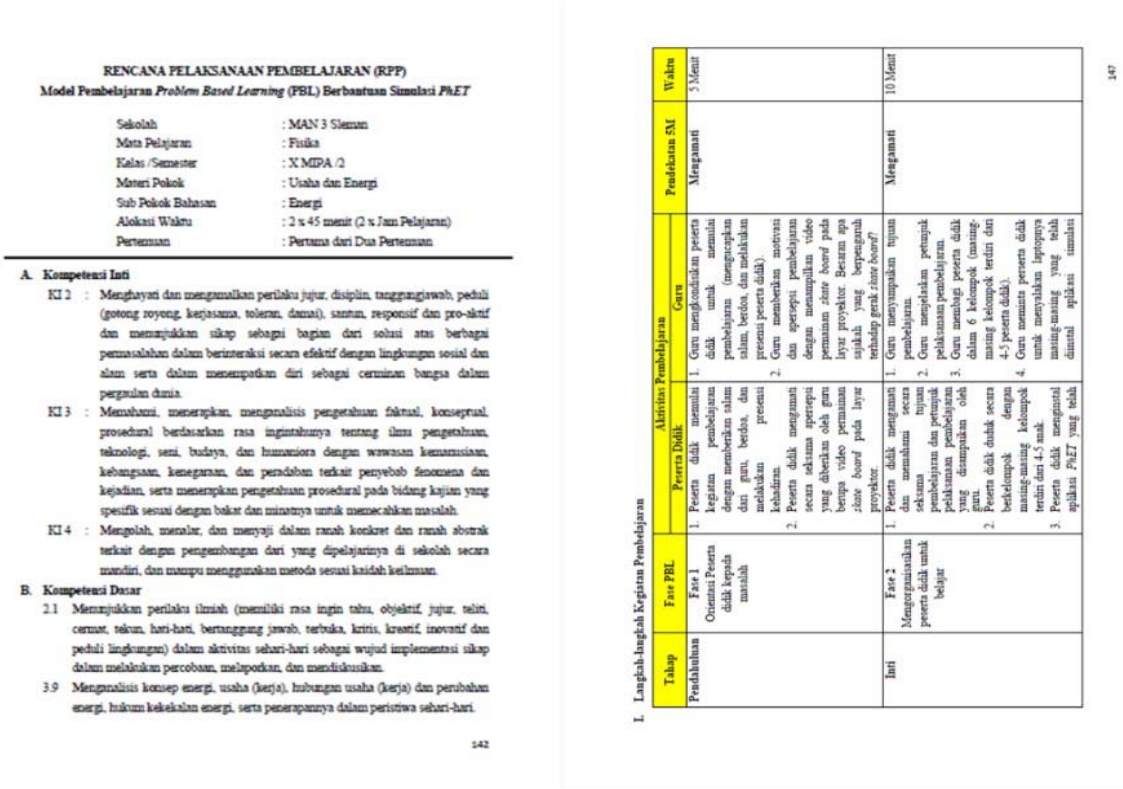
KI. 4 Mengolah, menalar, dan menyaji dalam ranah konkret dan ranah abstrak terkait dengan pengembangan dari yang dipelajarinya di sekolah secara mandiri, bertindak secara efektif dan kreatif, serta mampu menggunakan metoda sesuai kaidah keilmuan.

Kompetensi Dasar	Materi Pokok	Kegiatan Pembelajaran	Penilaian	Alokasi Waktu	Sumber Belajar
3.9 Menganalisis konsep energi, usaha (kerja), hubungan usaha (kerja) dan perubahan energi, hukum kekekalan energi, serta penerapannya dalam peristiwa sehari-hari. 4.9 Menerapkan metode ilmiah untuk mengajukan gagasan penyelesaian masalah gerak dalam kehidupan sehari-hari, yang berkaitan dengan konsep energi, usaha (kerja) dan hukum kekekalan energi.	Usaha dan Energi	**Fase 1. Orientasi peserta didik kepada masalah** Mengamati • Peserta didik memulai kegiatan pembelajaran dengan memberikan salam dari guru, berdoa, dan melakukan presensi kehadiran. • Peserta didik mengamati secara seksama apersepsi yang diberikan oleh guru berupa video permainan *skate board* pada layar proyektor. **Fase 2. Mengorganisasikan peserta didik untuk belajar** Mengamati • Peserta didik mengamati dan memahami secara seksama tujuan pembelajaran dan petunjuk pelaksanaan pembelajaran yang disampaikan oleh guru. • Peserta didik duduk secara berkelompok dengan masing-masing kelompok terdiri dari 4-5 anak. • Peserta didik menginstal aplikasi *PhET* yang telah diberikan oleh guru. • Peserta didik mendengarkan dan memahami langkah-langkah pengerjaan LKPD PBL secara berkelompok. **Fase 3. Membimbing Penyelidikan individu dan kelompok** Menanya • Peserta didik bertanya kepada guru terkait dengan video permainan *skate board* yang	Penilaian dilakukan melalui penilaian hasil pengerjaan LKPD PBL dengan rubrik terlampir dan soal tes kemampuan berpikir kritis.	2 JP	• Giancoli, Douglas C. (2005). *Fisika Jilid 1 (Terjemahan)*. Jakarta: Erlangga. • Sunardi dan Zaenab. (2014). *Fisika untuk SMA/MA Kelas XI Kelompok Peminatan Matematika dan Ilmu-ilmu Alam*. Bandung: Yrama Widya. • Tipler, Paul A. (2001). *Fisika untuk Sains dan Teknik Jilid 1 (Terjemahan)*. Jakarta: Erlangga. • LKPD PBL Berbasis Simulasi *PhET*. • Simulasi *PhET*

Figure 1. The physics syllabus of class X based on PhET simulation

(ii) PhET simulation based PBL lesson plan; the learning plan used as a guideline for the implementation of physics learning activities in this study contains a guide for teachers to teach, which consists of preliminary activities, core activities, and closing activities that are adjusted to the syntax of PBL models based on PhET simulations. In the preliminary activities, the teacher gives apperception and problems to students

about events in daily life related to work and energy. This preliminary phase has integrated the syntax of the earliest PBL model, i.e phase 1, the orientation of the students to the problem. After that, in the core activities of students form a study group consisting of 4-5 students. These study groups are formed randomly based on the draw they have obtained. This study group aims to solve the problems given by the physics teacher in the preliminary activities and also to solve work and energy problems in the worksheet that is distributed by the teacher with the assisted of a PhET simulation. PBL model syntax that plays a role in this core activity in the form of phase 2 organizes students to learn in groups; phase 3, guiding the investigation of these physical problems in groups; phase 4, develops and presents the work or results of investigations/solutions to problems discussed in groups; and phase 5, analyzing and evaluating the problem solving process carried out by students in groups. RPP based on PhET simulation based PBL model is expected to support learning activities with PhET simulation based PBL model, so that the aim of learning activities in the form of increasing students' critical thinking skills can be optimally improved. The PhET simulation based PBL lesson plan developed in this study can be shown in Figure 2 below.



RENCANA PELAKSANAAN PEMBELAJARAN (RPP)
Model Pembelajaran *Problem Based Learning* (PBL) Berbantuan Simulasi *PhET*

Sekolah	: MAN 3 Sleman
Mata Pelajaran	: Fisika
Kelas /Semester	: X MIPA /2
Materi Pokok	: Usaha dan Energi
Sub Pokok Bahasan	: Energi
Alokasi Waktu	: 2 x 45 menit (2 x Jam Pelajaran)
Pertemuan	: Pertama dari Dua Pertemuan

A. **Kompetensi Inti**
KI 2 : Menghayati dan mengamalkan perilaku jujur, disiplin, tanggungjawab, peduli (gotong royong, kerjasama, toleran, damai), santun, responsif dan pro-aktif dan menunjukkan sikap sebagai bagian dari solusi atas berbagai permasalahan dalam berinteraksi secara efektif dengan lingkungan sosial dan alam serta dalam menempatkan diri sebagai cerminan bangsa dalam pergaulan dunia.
KI 3 : Memahami, menerapkan, menganalisis pengetahuan faktual, konseptual, prosedural berdasarkan rasa ingintahunya tentang ilmu pengetahuan, teknologi, seni, budaya, dan humaniora dengan wawasan kemanusiaan, kebangsaan, kenegaraan, dan peradaban terkait penyebab fenomena dan kejadian, serta menerapkan pengetahuan prosedural pada bidang kajian yang spesifik sesuai dengan bakat dan minatnya untuk memecahkan masalah.
KI 4 : Mengolah, menalar, dan menyaji dalam ranah konkret dan ranah abstrak terkait dengan pengembangan dari yang dipelajarinya di sekolah secara mandiri, dan mampu menggunakan metoda sesuai kaidah keilmuan.

B. **Kompetensi Dasar**
3.1 Menganalisis konsep energi, usaha (kerja), hubungan usaha (kerja) dan perubahan energi, hukum kekekalan energi, serta penerapannya dalam peristiwa sehari-hari.

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I. Langkah-langkah Kegiatan Pembelajaran

Tahap	Fase PBL	Aktivitas Pembelajaran: Peserta Didik	Aktivitas Pembelajaran: Guru	Pendekatan 5M	Waktu
Pendahuluan				Mengamati	5 Menit
Inti	Fase 1 Orientasi Peserta didik kepada masalah	1. Peserta didik memulai kegiatan pembelajaran dengan memberikan salam dari guru, berdoa, dan melakukan presensi kehadiran. 2. Peserta didik mengamati secara seksama apersepsi yang diberikan oleh guru berupa video permainan *skate board* pada layar proyektor.	1. Guru mengkondisikan peserta didik untuk memulai pembelajaran (mengucapkan salam, berdoa, dan melakukan presensi peserta didik). 2. Guru memberikan motivasi dan apersepsi pembelajaran dengan menampilkan video permainan *skate board* pada layar proyektor. Bagaimana apa sajakah yang berpengaruh terhadap gerak *skate board*?	Mengamati	10 Menit
	Fase 2 Mengorganisasikan peserta didik untuk belajar	1. Peserta didik mengamati dan memahami secara seksama pembelajaran dan petunjuk pelaksanaan pembelajaran yang disampaikan oleh guru. 2. Peserta didik duduk secara berkelompok dengan masing-masing kelompok terdiri dari 4-5 anak. 3. Peserta didik mengunduh aplikasi *PhET* yang telah	1. Guru menyampaikan tujuan pembelajaran. 2. Guru menjelaskan petunjuk pelaksanaan pembelajaran. 3. Guru membagi peserta didik dalam 6 kelompok (masing-masing kelompok terdiri dari 4-5 peserta didik). 4. Guru meminta peserta didik untuk menyalakan laptopnya masing-masing yang telah diinstal aplikasi simulasi		

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Figure 2. The PhET simulation based PBL lesson plan

(iii) PhET simulation; learning medium used in this research is to apply simulation-based learning medium that already exist in the form of PhET simulation. Learning medium in the form of PhET simulation is used as a stimulus given to students so that students can easily research the related chapter of work and energy, so that the critical thinking skills of students can increase optimally. Learning medium in the form of PhET simulation is a medium that simulates events or missions in everyday life such as skate board games that have a relationship with the chapter work and energy. The PhET simulation developed in this study can be shown in Figure 3 below.

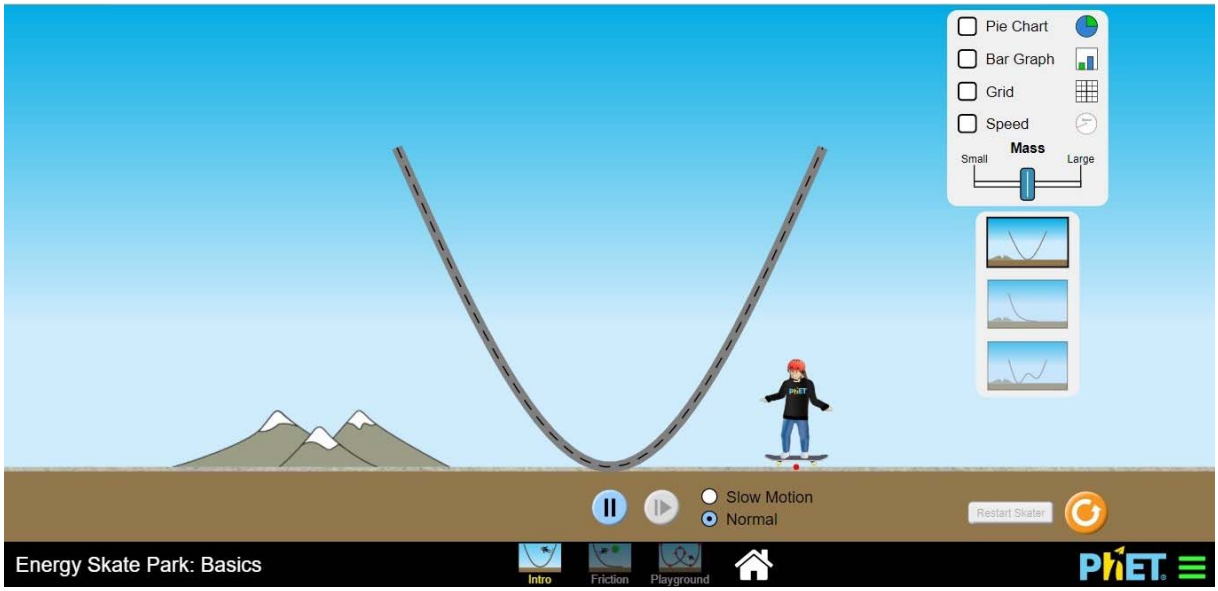


Figure 3. The PhET simulation

(iv) The students worksheet (LKPD) PBL based on PhET simulation; this student worksheet (LKPD) PBL based on a PhET simulation is used to determine the achievement of students' understanding after studying the work and energy chapter through a PhET simulation. The LKPD PBL was compiled based on learning objectives and developed according to the syntax in the PBL model based on the PhET simulation. In addition, this LKPD contains a summary of work and energy material, steps for using the PhET simulation along with pictures and instructions for use, and problems regarding work and energy chapter related to the PhET simulation. Do not forget also every part in LKPD is integrated with the syntax or phases

contained in the PBL model, and the problems contained in LKPD are also adjusted to the indicators of students' critical thinking skills. The PBL phases used in the development of LKPD are in the form of organizing students to learn and developing and presenting students' work. The LKPD PBL model developed in this study can be shown in Figure 4 below.

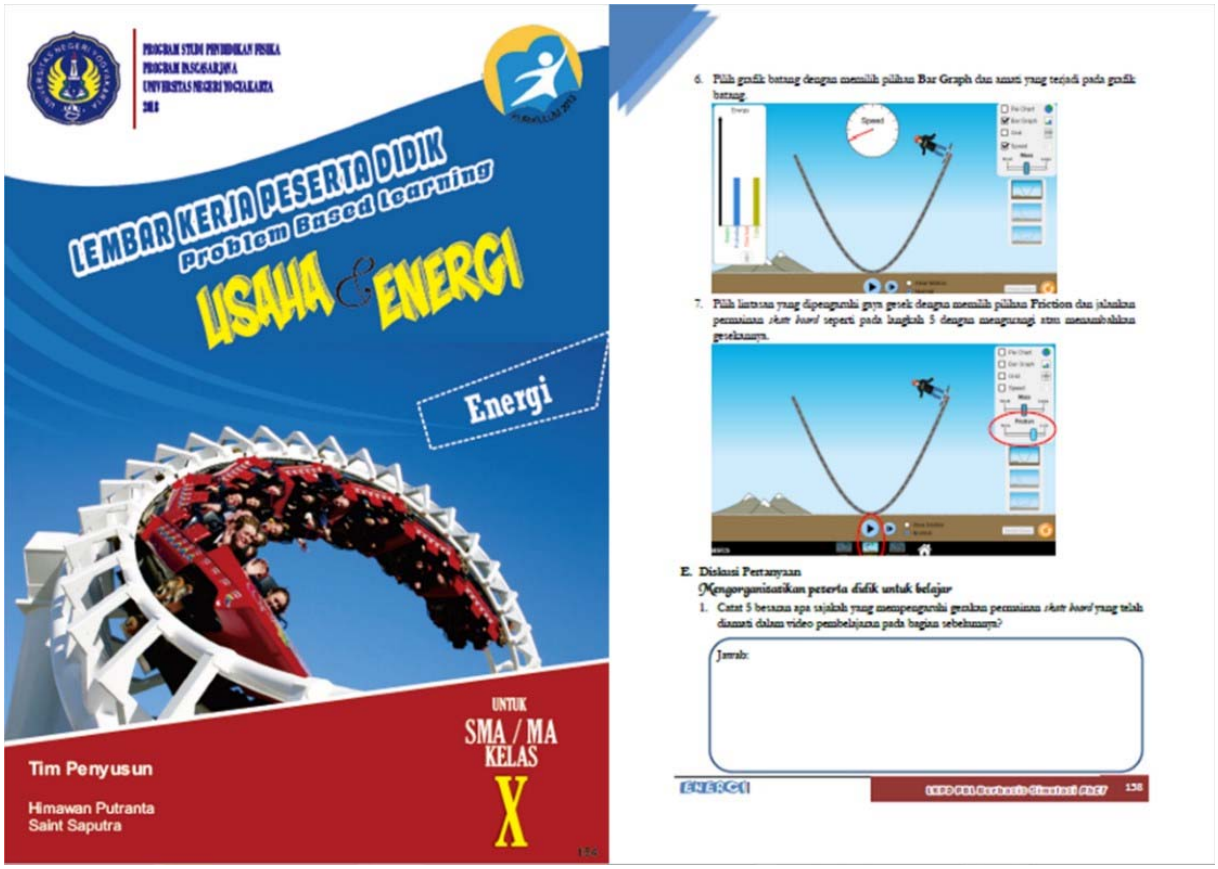


Figure 4. Students worksheet (LKPD) PBL based on PhET simulation

In general, the stages carried out in this study apply the 4D research model. The stage diagram of this research can be observed in the following Figure 5.

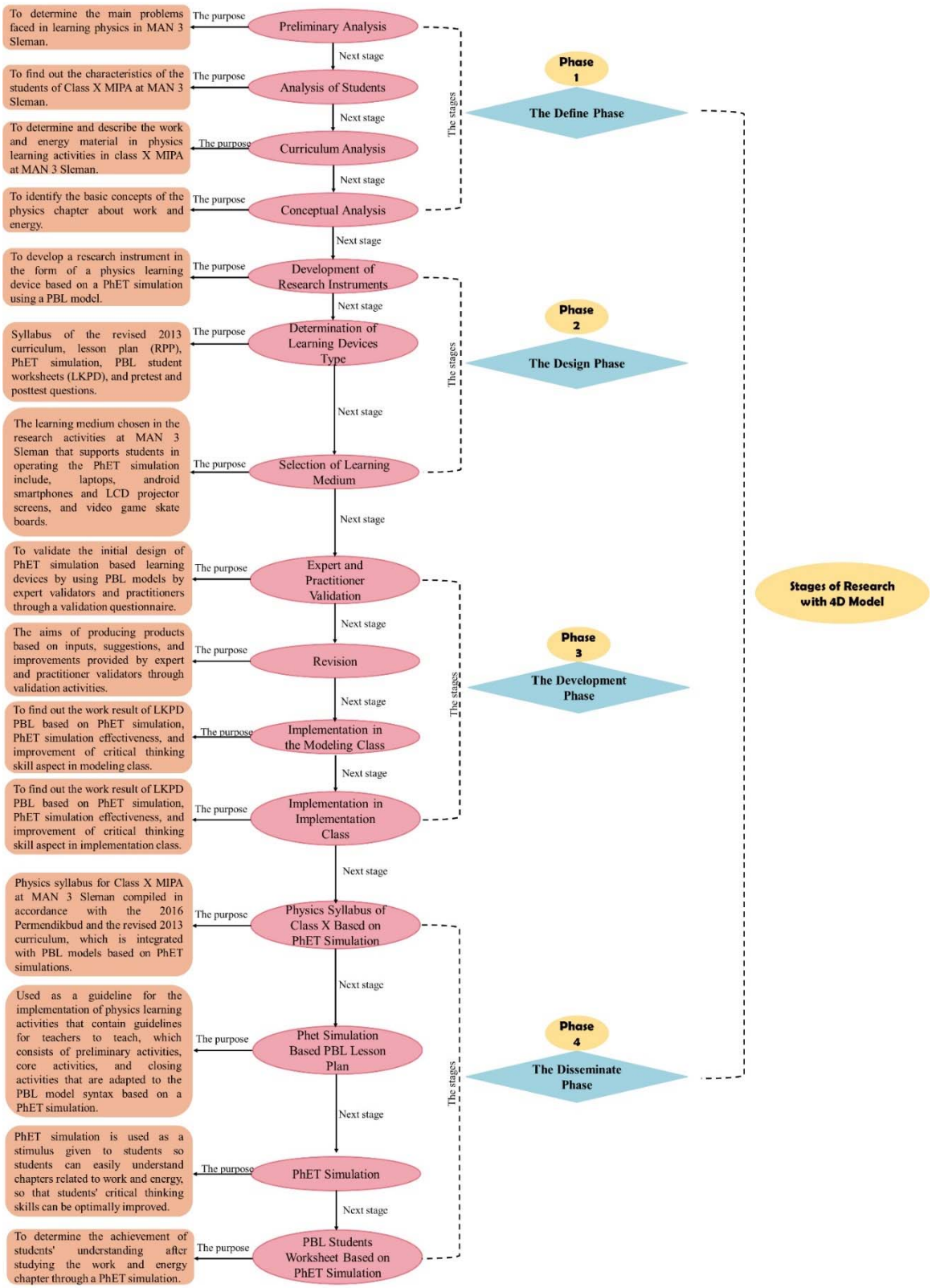
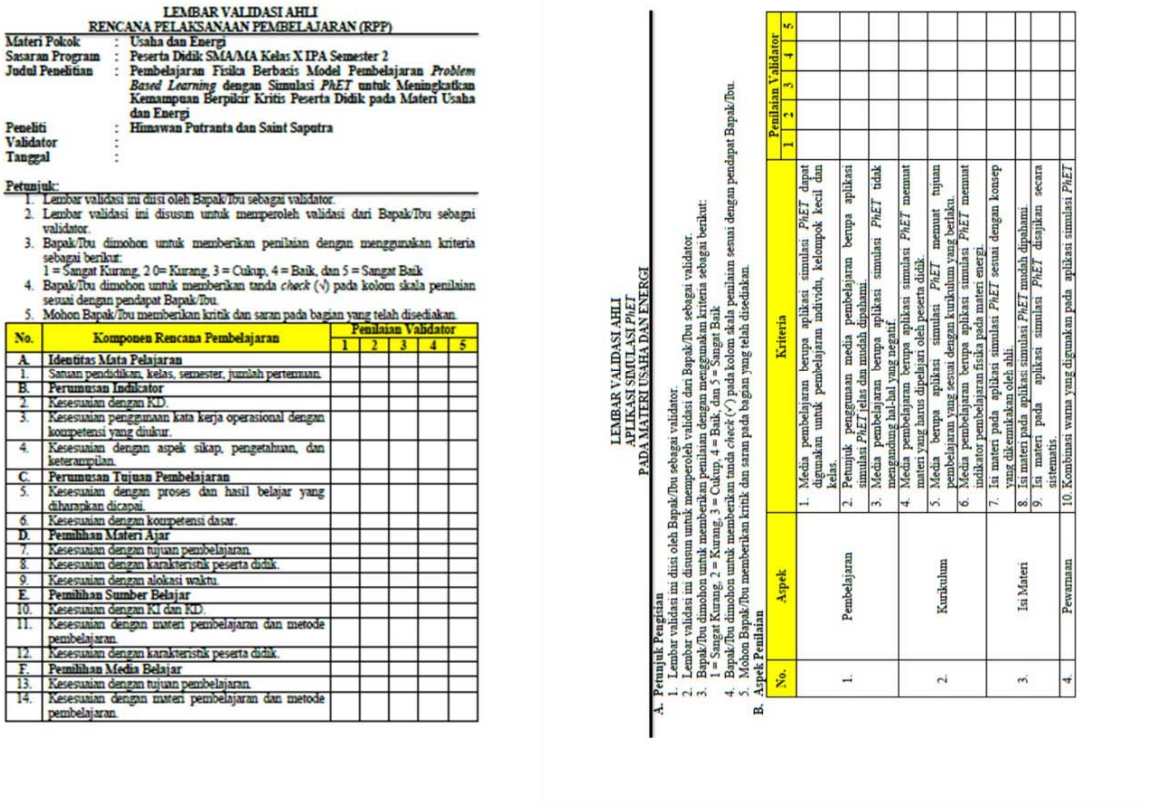


Figure 5. Diagram of the stages of research using the 4D model

Meanwhile, the data collection instruments used in this study were a validation questionnaire, a student response questionnaire, and a critical thinking skills test. The details and elaboration of the data collection instruments used in this study are as follows. (i) Validation questionnaire; validation questionnaires are used to get reviewers along with feedback and suggestions for improvement from expert and practitioner validators to PBL learning devices based on PhET simulations. PBL learning devices based on PhET simulations have been developed in the form of RPP PBL based on PhET simulations, PhET simulations, LKPD PBL based on PhET simulations, and critical thinking skills tests. The questionnaire used to validate the RPP PBL based on the PhET simulation contains multiple choice questions about aspects of assessment in the RPP, i.e aspects of lesson plan identity, formulation of indicators, formulation of learning objectives, selection of physics chapter, selection of medium and learning resources, learning models, scenarios learning, and assessment. The questionnaire used to validate the PhET simulation contains questions about aspects of ease of operation, appearance, material suitability, and language. The questionnaire used to validate the LKPD PBL based on the PhET simulation contained questions about the didactic aspects, the quality of the material in the LKPD, and the suitability of the LKPD PBL with the PhET simulation. Meanwhile, the questionnaire used to validate the critical thinking skills test contained questions about aspects of the learning guide, the quality of physics chapter in the test, pictures and language, and aspects of conformity with the indicators of critical thinking skills. The validation questionnaire used in this study can be shown in Figure 6.



LEMBAR VALIDASI AHLI
RENCANA PELAKSANAAN PEMBELAJARAN (RPP)

Materi Pokok : Usaha dan Energi
Sasaran Program : Peserta Didik SMA/MA Kelas X IPA Semester 2
Judul Penelitian : Pembelajaran Fisika Berbasis Model Pembelajaran *Problem Based Learning* dengan Simulasi *PhET* untuk Meningkatkan Kemampuan Berpikir Kritis Peserta Didik pada Materi Usaha dan Energi
Peneliti : Himawan Putranta dan Saint Saputra
Validator :
Tanggal :

Petunjuk:
1. Lembar validasi ini diisi oleh Bapak/Ibu sebagai validator.
2. Lembar validasi ini disusun untuk memperoleh validasi dari Bapak/Ibu sebagai validator.
3. Bapak/Ibu dimohon untuk memberikan penilaian dengan menggunakan kriteria sebagai berikut:
   1 = Sangat Kurang, 2 0= Kurang, 3 = Cukup, 4 = Baik, dan 5 = Sangat Baik
4. Bapak/Ibu dimohon untuk memberikan tanda *check* (√) pada kolom skala penilaian sesuai dengan pendapat Bapak/Ibu.
5. Mohon Bapak/Ibu memberikan kritik dan saran pada bagian yang telah disediakan.

No.	Komponen Rencana Pembelajaran	Penilaian Validator				
		1	2	3	4	5
A.	**Identitas Mata Pelajaran**					
1.	Satuan pendidikan, kelas, semester, jumlah pertemuan.					
B.	**Perumusan Indikator**					
2.	Kesesuaian dengan KD.					
3.	Kesesuaian penggunaan kata kerja operasional dengan kompetensi yang diukur.					
4.	Kesesuaian dengan aspek sikap, pengetahuan, dan keterampilan.					
C.	**Perumusan Tujuan Pembelajaran**					
5.	Kesesuaian dengan proses dan hasil belajar yang diharapkan dicapai.					
6.	Kesesuaian dengan kompetensi dasar.					
D.	**Pemilihan Materi Ajar**					
7.	Kesesuaian dengan tujuan pembelajaran.					
8.	Kesesuaian dengan karakteristik peserta didik.					
9.	Kesesuaian dengan alokasi waktu.					
E.	**Pemilihan Sumber Belajar**					
10.	Kesesuaian dengan KI dan KD.					
11.	Kesesuaian dengan materi pembelajaran dan metode pembelajaran.					
12.	Kesesuaian dengan karakteristik peserta didik.					
F.	**Pemilihan Media Belajar**					
13.	Kesesuaian dengan tujuan pembelajaran.					
14.	Kesesuaian dengan materi pembelajaran dan metode pembelajaran.					

LEMBAR VALIDASI AHLI
APLIKASI SIMULASI *PhET*
PADA MATERI USAHA DAN ENERGI

A. Petunjuk Pengisian
1. Lembar validasi ini diisi oleh Bapak/Ibu sebagai validator.
2. Lembar validasi ini disusun untuk memperoleh validasi dari Bapak/Ibu sebagai validator.
3. Bapak/Ibu dimohon untuk memberikan penilaian dengan menggunakan kriteria sebagai berikut:
   1 = Sangat Kurang, 2 = Kurang, 3 = Cukup, 4 = Baik, dan 5 = Sangat Baik
4. Bapak/Ibu dimohon untuk memberikan tanda *check* (√) pada kolom skala penilaian sesuai dengan pendapat Bapak/Ibu.
5. Mohon Bapak/Ibu memberikan kritik dan saran pada bagian yang telah disediakan.

B. Aspek Penilaian

No.	Aspek	Kriteria	Penilaian Validator				
			1	2	3	4	5
1.	Pembelajaran	1. Media pembelajaran berupa aplikasi simulasi *PhET* dapat digunakan untuk pembelajaran individu, kelompok kecil dan kelas.					
		2. Petunjuk penggunaan media pembelajaran berupa aplikasi simulasi *PhET* jelas dan mudah dipahami.					
		3. Media pembelajaran berupa aplikasi simulasi *PhET* tidak mengandung hal-hal yang negatif.					
2.	Kurikulum	4. Media pembelajaran berupa aplikasi simulasi *PhET* memuat materi yang harus dipelajari oleh peserta didik.					
		5. Media berupa aplikasi simulasi *PhET* memuat tujuan pembelajaran yang sesuai dengan kurikulum yang berlaku					
		6. Media pembelajaran berupa aplikasi simulasi *PhET* memuat indikator pembelajaran fisika pada materi energi.					
3.	Isi Materi	7. Isi materi pada aplikasi simulasi *PhET* sesuai dengan konsep yang dikemukakan oleh ahli.					
		8. Isi materi pada aplikasi simulasi *PhET* mudah dipahami.					
		9. Isi materi pada aplikasi simulasi *PhET* disajikan secara sistematis.					
4.	Pewarnaan	10. Kombinasi warna yang digunakan pada aplikasi simulasi *PhET*					

Figure 6. The validation questionnaire

(ii) Students response questionnaire; student response questionnaire is a questionnaire given to students to request their responses to the use of PBL-based PhET simulation learning devices that have been developed in physics learning. The student response questionnaire used in this study consisted of two student response questionnaires, i.e the student response questionnaire to the PhET simulation and LKPD PBL based on the PhET simulation. The student response questionnaire to the PhET simulation contained questions about aspects of the quality of the material, pleasure, linguistics, learning independence, and aspects of using illustrations. Furthermore, the student response questionnaire to LKPD PBL based on this PhET simulation contained questions about aspects of appearance, language, and aspects of critical thinking skills. The results of the student questionnaire responses are part of the validation of PBL learning devices based on the developed PhET simulations. Meanwhile, the questionnaire responses of students to the simulation of PhET and LKPD PBL based on the simulation of PhET can be shown in Figure 7.

(a)

ANGKET RESPON PESERTA DIDIK TERHADAP LKPD PBL BERBASIS SIMULASI *PhET* PADA MATERI USAHA DAN ENERGI

Petunjuk Pengisian:

1. Jawablah angket ini sejujurnya karena tujuan pengisian angket ini adalah:
   a. Mengetahui penilaian Anda terhadap pembelajaran yang Anda alami selama menggunakan LKPD PBL berbasis simulasi *PhET* pada materi Usaha dan Energi.
   b. Menjadi bahan pertimbangan dalam merencanakan perbaikan kegiatan pembelajaran Fisika di masa yang akan datang.
2. Berilah tanda cek (✓) pada kolom yang sesuai dengan pendapat Anda pada tempat yang tersedia dengan keterangan skor sebagai berikut:
   1 = Sangat Kurang, 2 = Kurang, 3 = Cukup, 4 = Baik, dan 5 = Sangat Baik
3. Mohon Anda memberikan kritik dan saran pada bagian yang telah disediakan.

No.	Uraian	Skor				
		1	2	3	4	5
	Aspek Tampilan					
1.	Cover LKPD PBL berbasis simulasi *PhET* menarik minat saya dalam belajar.					
2.	Gambar dalam LKPD PBL berbasis simulasi *PhET* menarik minat saya dalam mengerjakan LKPD ini.					
3.	Gambar yang disajikan menimbulkan makna ganda.					
4.	Kalimat yang digunakan dalam LKPD sederhana, lugas, dan mudah dipahami.					
5.	LKPD PBL berbasis simulasi *PhET* disajikan dalam kalimat yang menimbulkan makna ganda.					
	Aspek Kemampuan Berpikir Kritis					
6.	Permasalahan dalam LKPD PBL berbasis simulasi *PhET* membantu saya untuk mengatasi permasalahan fisika yang ada.					
7.	Penggunaan LKPD PBL berbasis simulasi *PhET* membantu saya dalam meningkatkan kemampuan berpikir kritis.					
8.	Penggunaan LKPD PBL berbasis simulasi *PhET* membuat saya sulit dalam menganalisis masalah yang terkait dengan energi.					
9.	Adanya pertanyaan dalam LKPD PBL berbasis simulasi *PhET* belum mampu mendorong saya untuk mengkombinasikan antara masalah satu dengan yang lain.					
10.	Penggunaan LKPD PBL berbasis simulasi *PhET* membuat saya mudah dalam menganalisis materi energi.					
11.	Penggunaan LKPD PBL berbasis simulasi *PhET* sulit membantu saya dalam menyimpulkan kegiatan					

(b)

ANGKET RESPON PESERTA DIDIK TERHADAP APLIKASI SIMULASI *PhET* PADA MATERI USAHA DAN ENERGI

Petunjuk Pengisian:

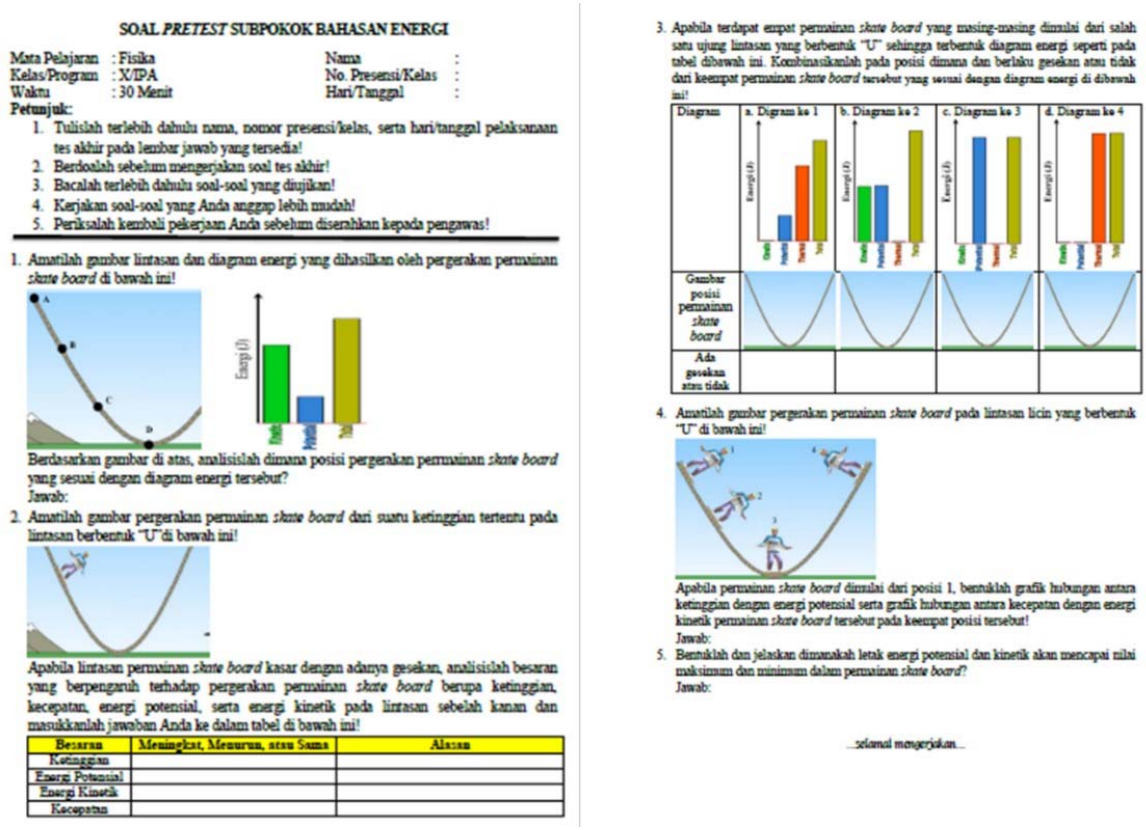
1. Jawablah angket ini sejujurnya karena tujuan pengisian angket ini adalah:
   a. Mengetahui penilaian Anda terhadap pembelajaran yang Anda alami selama menggunakan aplikasi simulasi *PhET* pada materi Usaha dan Energi.
   b. Menjadi bahan pertimbangan dalam merencanakan perbaikan kegiatan pembelajaran Fisika di masa yang akan datang.
2. Berilah tanda cek (✓) pada kolom yang sesuai dengan pendapat Anda pada tempat yang tersedia dengan keterangan skor sebagai berikut:
   1 = Sangat Kurang, 2 = Kurang, 3 = Cukup, 4 = Baik, dan 5 = Sangat Baik
3. Mohon Anda memberikan kritik dan saran pada bagian yang telah disediakan.

No.	Uraian	Skor				
		1	2	3	4	5
	Aspek Kualitas Isi					
1.	Media pembelajaran berupa aplikasi simulasi *PhET* dapat digunakan dengan mudah.					
2.	Petunjuk penggunaan media pembelajaran berupa aplikasi simulasi *PhET* membingungkan.					
3.	Media pembelajaran berupa aplikasi simulasi *PhET* tidak mengandung hal-hal positif bagi saya.					
4.	Gambar yang disajikan dalam aplikasi simulasi *PhET* jelas dan mudah dipahami.					
	Aspek Rasa Senang					
6.	Saya merasa senang menggunakan media pembelajaran berupa aplikasi simulasi *PhET* ini.					
7.	Saya merasa bosan ketika menggunakan media pembelajaran berupa aplikasi simulasi *PhET* ini.					
	Aspek Kebahasaan					
8.	Bahasa yang digunakan dalam aplikasi simulasi *PhET* ini mudah dimengerti.					
9.	Terdapat kalimat yang membingungkan dalam aplikasi simulasi *PhET* ini.					
	Aspek Kemandirian Belajar					
10.	Saya termotivasi belajar materi energi setelah menggunakan aplikasi simulasi *PhET* ini.					
11.	Media pembelajaran ini mendorong saya untuk bersungguh-sungguh dalam mengerjakan tugas secara mandiri.					
12.	Aplikasi simulasi *PhET* ini sulit digunakan untuk belajar secara mandiri.					
	Aspek Penggunaan Ilustrasi					
13.	Animasi pada aplikasi simulasi *PhET* ini menarik.					
14.	Ilustrasi yang digunakan berhubungan dengan kehidupan sehari-hari.					
15.	Ilustrasi yang digunakan menyulitkan saya dalam memahami materi energi.					

Figure 7. The questionnaire responses of students, i.e (a) to the LKPD PBL based on the simulation of PhET, (b) to the simulation of PhET

(iii) The critical thinking test; the assessment instrument developed and used in this study was in the form of open ended test questions that demanded students' answers in writing based on the work and energy concepts they knew with a total of 5 items. This assessment instrument is given to students in the modeling class and the implementation class in the form of pretests whose implementation is before they get work materials and energy assisted by PhET simulations and posttest is given to students after they get work materials and energy assisted by PhET simulations. This assessment instrument was prepared based on indicators of students' critical thinking skills in accordance with Bloom's revised taxonomy in the cognitive domain in the form of analytical skills (C4) and skills to combine (C6) related to the work and

energy chapter. The critical thinking skills assessment instrument developed by researchers and used in this study can be shown in Figure 8.


SOAL *PRETEST* SUBPOKOK BAHASAN ENERGI

Mata Pelajaran : Fisika
Kelas/Program : X/IPA
Waktu : 30 Menit
Nama :
No. Presensi/Kelas :
Hari/Tanggal :

Petunjuk:
1. Tulislah terlebih dahulu nama, nomor presensi/kelas, serta hari/tanggal pelaksanaan tes akhir pada lembar jawab yang tersedia!
2. Berdoalah sebelum mengerjakan soal tes akhir!
3. Bacalah terlebih dahulu soal-soal yang diujikan!
4. Kerjakan soal-soal yang Anda anggap lebih mudah!
5. Periksalah kembali pekerjaan Anda sebelum diserahkan kepada pengawas!

1. Amatilah gambar lintasan dan diagram energi yang dihasilkan oleh pergerakan permainan *skate board* di bawah ini!

Berdasarkan gambar di atas, analisislah dimana posisi pergerakan permainan *skate board* yang sesuai dengan diagram energi tersebut?
Jawab:

2. Amatilah gambar pergerakan permainan *skate board* dari suatu ketinggian tertentu pada lintasan berbentuk "U"di bawah ini!

Apabila lintasan permainan *skate board* kasar dengan adanya gesekan, analisislah besaran yang berpengaruh terhadap pergerakan permainan *skate board* berupa ketinggian, kecepatan, energi potensial, serta energi kinetik pada lintasan sebelah kanan dan masukkanlah jawaban Anda ke dalam tabel di bawah ini!

Besaran	Meningkat, Menurun, atau Sama	Alasan
Ketinggian		
Energi Potensial		
Energi Kinetik		
Kecepatan		

3. Apabila terdapat empat permainan *skate board* yang masing-masing dimulai dari salah satu ujung lintasan yang berbentuk "U" sehingga terbentuk diagram energi seperti pada tabel dibawah ini. Kombinasikanlah pada posisi dimana dan berlaku gesekan atau tidak dari keempat permainan *skate board* tersebut yang sesuai dengan diagram energi di dibawah ini!

Diagram	a. Diagram ke 1	b. Diagram ke 2	c. Diagram ke 3	d. Diagram ke 4
Gambar posisi permainan *skate board*				
Ada gesekan atau tidak				

4. Amatilah gambar pergerakan permainan *skate board* pada lintasan licin yang berbentuk "U" di bawah ini!

Apabila permainan *skate board* dimulai dari posisi 1, buatlah grafik hubungan antara ketinggian dengan energi potensial serta grafik hubungan antara kecepatan dengan energi kinetik permainan *skate board* tersebut pada keempat posisi tersebut!
Jawab:

5. Buatlah dan jelaskan dimanakah letak energi potensial dan kinetik akan mencapai nilai maksimum dan minimum dalam permainan *skate board*?
Jawab:

...selamat mengerjakan...

Figure 8. The critical thinking skills assessment instrument

Instrument Analysis

Meanwhile, the instruments that have been developed by these researchers are then analyzed for their validity and reliability. The instruments analyzed for their validity and reliability in this study included the feasibility of using lesson plans based on PhET simulations, PhET simulations, PBL student worksheets based on PhET simulations, and critical thinking skills tests. The feasibility of PBL learning devices based on PhET simulations that have been developed in the form of RPP PBL based on PhET simulations, PhET simulations, LKPD PBL based on PhET simulations, and critical thinking skills test instruments are obtained from validation scores given by expert and practitioner validators and student response results. Therefore, to analyze the feasibility of PBL learning devices based on PhET simulations that have

been developed in the form of RPP PBL based on PhET simulations, PhET simulations, LKPD PBL based on PhET simulations, and critical thinking skills tests obtained from validator assessment and student response results are carried out using the Aiken V equation as shown in Equation 1.

$$V = \sum \frac{s}{[n(c-1)]} = \sum \frac{r - l_o}{[n(c-1)]} \quad (1)$$

In this case, s is the judge to n, l_o is the lowest validity score, c is the highest validity score, and r is the number given by the assessor to n. Meanwhile, Azwar (2015) stated that the criterion of the validity score of a valuation instrument or learning device obtained based on equation 1 is divided into 5 as shown in Table 1 below.

Table 1. Criteria score of Aiken's V validity

Validity Score	Category
0.8≤V≤1.0	Very Good
0.6≤V≤0.8	Good
0.4≤V≤0.6	Quite Good
0.2≤V≤0.4	Bad
V≤0.2	Very Bad

After the validation and response students to of learning device PBL based on PhET simulation that has been developed in the form of RPP PBL based on PhET simulation, PhET simulation, LKPD PBL based on PhET simulation, and critical thinking thinking test are analyzed using Aiken's V equation, the next step is to analyze reliability scores of earning device PBL based on PhET simulation that have been done by students in the form of LKPD PBL based on PhET simulation and test of critical thinking skills. The result of reliability analysis from LKPD PBL based on PhET simulation and critical thinking skills test is obtained using percentage of agreement (PA) equation analysis. The way to determine the reliability of LKPD PBL based on PhET simulation and critical thinking skills test is by correcting and evaluating the results of students' work on LKPD PBL based on PhET simulation

and critical thinking skills test by two assessors and then tested approval level using the percentage of equation agreement (PA) as shown in Equation 2 (Borich, 1994).

$$\mathrm{PA} = \left(1 - \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A} + \mathrm{B}}\right) \times 100\% \qquad (2$$

In this case, the PA is the value of the percentage of agreement, A represents a higher total score of the assessor, and B represents a lower total score of the assessor. Based on the value of PA can be known level of approval LKPD PBL based on PhET simulation and the critical thinking test, provided that the percentage agreement value of ≥ 75% and it can be stated that both assessors agree or reliable.

Data analysis

Meanwhile, for data analysis in this study begins by analyzing the effectiveness of instructional media used in the modeling class and implementation class. The effectiveness of instructional medium used in physics learning activities in the modeling class and implementation class in the form of PhET simulation is done by reviewing the effectiveness of PhET simulation from improving the critical thinking skills of students according to Minimum Exhaustiveness Criteria (KKM) in modeling class and class implementation. This PhET simulation effectiveness analysis uses a one-sample t-test technique using the SPSS 21 program. The decision criteria used is Ho rejected if the value of sig. obtained through the SPSS program less than the significance level (α) of 0.05. The reference used in this PhET simulation effectiveness test is 75, which is a Minimum Exhaustiveness Criterion (KKM) score that must be reached by the students after following the physics learning activity using PhET simulation. This value becomes a reference to determine the effectiveness of PhET simulation applied in the learning activity in terms of improvement of students' critical thinking skills to KKM in modeling class and implementation class. Improvement students' critical thinking skills in modeling class and implementation class can be seen through the work of pretest and posttest questions of PhET simulation-based critical thinking skills analyzed using standard gain equations. This technique is done by calculating the value of the gain (Hake, 2012). The standard gain equation used is as shown in Equation 3 below.

$$\text{std gain} < g > = \frac{\text{posttest sore} - \text{pretest score}}{\text{maximum score} - \text{pretest score}} \qquad (3)$$

In this case g is the standard gain, the post test score is the posttest score obtained by each students, the pretest score is the pretest score obtained by each students, and the maximum score is the likelihood of the students to obtain the greatest score. Based on the information, the maximum score in pretest and posttest in this research is 43. Meanwhile, the interpretation of standard gain values is found in several criteria as in Table 2 below (Hake, 2012).

Table 2. Criteria of Standard Gain Value

Standard Gain Score (g)	Criteria
g>0.7	High
0.3<g<0.7< span=""></g<0.7<>	Medium
g<0.3	Low

After we develop a research instrument for data collection, the next step is to analyze the instrument and analyze the data. The steps that must be considered in the analysis of instruments and data analysis in this study can be observed in the following Figure 9.

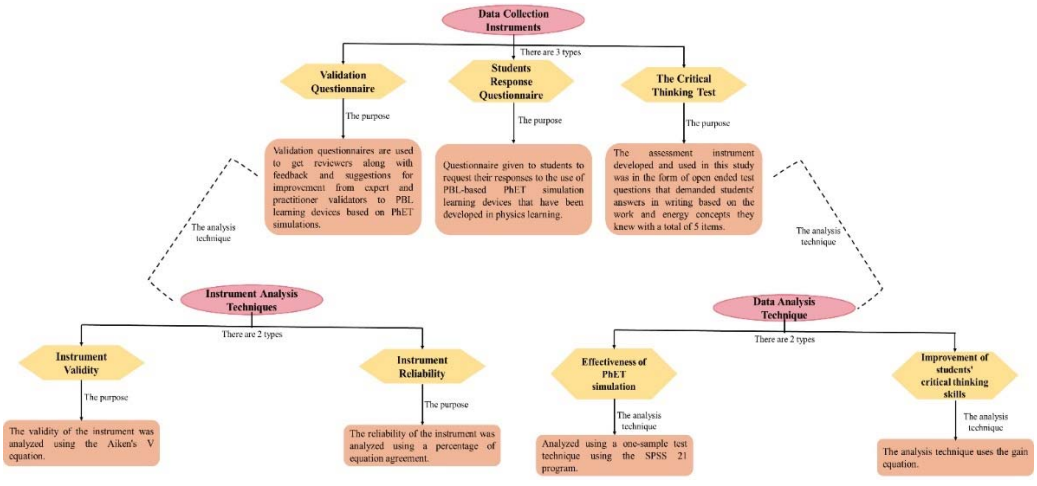


Figure 8. Diagram of steps in instrument analysis and data analysis

Result and Discussion

The results of the analysis of the instrument in the form of learning devices PhET simulations-assisted using PBL model

After we know together about what data is sought in this study by using instruments that researchers have developed, then we first need to know about the feasibility of research instruments in the form of learning devices PhET simulations-assisted using PBL models that researchers have developed. The feasibility data of this research instrument is in the form of data on the validity and reliability of the instruments that have been provided by expert and practitioner validators, and have been analyzed using equations 1 and 2. The first analysis of the research instrument was to analyze the feasibility (validity and reliability) of the learning devices PhET simulation-assisted using problem based learning (PBL) model. Meanwhile, the results of the analysis of the validity of learning devices PhET simulation-assisted using PBL model can be shown in Table 3 below.

Table 3. Validation results of learning devices PhET simulation-assisted using PBL model

No.	Assessment Item	Validity (V)	Category
RPP PBL Based on PhET Simulation			
A.	Subject Identity	0.92	Very Good
B.	Formulation of Indicators	0.80	Very Good
C.	Formulation of Learning Objectives	0.79	Good
D.	Selection of Teaching Materials	0.86	Very Good
E.	Selection of Learning Resources	0.80	Very Good
F.	Selection of Learning Medium	0.83	Very Good
G.	Learning Model	0.92	Very Good
H.	Learning Scenarios	0.79	Good
I.	Assessment	0.79	Good
	Validity of RPP PBL Based on PhET Simulation	**0.82**	**Very Good**
PhET Simulation			
A.	Learning	0.78	Good

B.	Curriculum	0.75	Good
C.	Materials Content	0.78	Good
D.	Coloring	0.79	Good
E.	Word and Language Spelling	0.78	Good
F.	Display on Screen	0.89	Very Good
G.	Instructions	0.92	Very Good
	Validity of PhET Simulation	**0.81**	**Very Good**
LKPD PBL Based on PhET Simulation			
A.	The Didactic Aspect	0.79	Good
B.	The Quality Aspects of Material in LKPD	0.80	Very Good
C.	The Aspects of Compliance LKPD PBL Based on PhET Simulation	0.83	Very Good
	Validity of LKPD PBL Based on PhET Simulation	**0.80**	**Very Good**
Critical Thinking Test			
A.	The Aspects of Learning Guides	0.83	Good
B.	The Quality Aspects of Matter in Test	0.78	Good
C.	The Aspects of Pictures and Language	0.87	Very Good
D.	The Aspects of Conformity of Critical Thinking Test	0.79	Good
	Validity of Critical Thinking Skills Test	**0.83**	**Very Good**
	Validity of learning devices PhET simulation-assisted using PBL model	**0.82**	**Very Good**

Based on the results of the validation of the instruments used in this study which can be shown in Table 3, the results of the validity of learning devices PhET simulation-assisted using PBL models of 0.82 with very good categories. With the details, the results of the validity of the LKPD PBL based on PhET simulation are 0.82 with a very good category, the results of the validity of the learning media in the form of PhET simulations are 0.81 which are included in the very good category, the results of the LKPD PBL validity based on the PhET simulation are equal to 0.80 which is included in the excellent category, and the results of the validity of the critical thinking skills test that is equal to 0.83 which is included in the excellent category.

Therefore, it can be stated that the learning devices PhET simulation-assisted using PBL models consisting of RPP PBL based on PhET simulation, PhET simulation, LKPD PBL based on PhET simulations, and critical thinking skills tests are valid and suitable for use in physics learning class X MIPA in MAN 3 Sleman consisting of modeling class and implementation class.

The learning device can be declared appropriate in accordance with the results of the validity provided by expert and practitioner validators, so that the learning device can be used in all class X MIPA whose characteristics of students and other characteristics are similar to the characteristics of class X MIPA students in MAN 3 Sleman. This is consistent with the view of Hasibuan *et al.*. (2018) which states that a learning device that is developed and meets the established eligibility standards, then the learning device can be used in physics-specific learning activities in all high schools with homogeneous characteristics and possible learning objectives can be achieved well. However, the results of the validity of the learning devices developed by researchers in this study were not in the highest validity scores in the excellent category. However, the validity score of this learning device is close to the lowest score in the excellent category. This is a lot of factors that influence it, can be influenced by the number of validators that are less numerous and also the valuation of validiators that tend to be random which assesses in the lowest to highest assessment range. The results of a random assessment by the validiator from the lowest to highest assessment range are characteristic of a learning instrument or device that is valid or feasible to be used in research (Huang & Chiu, 2015).

After the instruments used in this study were analyzed for validity using the Aiken's V equation, the next step was to analyze the other parts of the feasibility, i.e analyzing the reliability of the research instrument or the reliability of PBL learning devices assisted with PhET simulations. In other words, the results of the reliability are also used as part of the feasibility of the PBL learning device assisted by PhET simulations that have been developed by researchers. The results of the PBL learning device assisted by the PhET simulation for energy sub-subjects in the modeling class and implementation class can be presented in Table 4 below.

Table 4. Reliability of learning devices PhET simulation-assisted using PBL model

Reliability of LKPD PBL Based on PhET Simulation				
Item number of LKPD PBL Based on PhET Simulation	**Modeling Class**		**Implementation Class**	
	Average of PA per Item (%)	**Category**	**Average of PA per Item (%)**	**Category**
1.	95.14	Reliable	93.93	Reliable
2.	95.98	Reliable	93.86	Reliable
3.	97.20	Reliable	95.59	Reliable
4.	94.46	Reliable	94.46	Reliable
5.	97.22	Reliable	93.44	Reliable
6.	94.11	Reliable	96.28	Reliable
7.	98.01	Reliable	94.72	Reliable
Quantity	**96.27**	**Reliable**	**95.31**	**Reliable**
Reliability of Pretest on Critical Thinking Skills				
Item number of Pretest on Critical Thinking Skills	**Modeling Class**		**Implementation Class**	
	Average of PA per Item (%)	**Category**	**Average of PA per Item (%)**	**Category**
1.	91.64	Reliable	91.33	Reliable
2.	94.87	Reliable	96.32	Reliable
3.	98.17	Reliable	98.65	Reliable
4.	96.61	Reliable	97.75	Reliable
5.	97.52	Reliable	96.21	Reliable
Quantity	**96.54**	**Reliable**	**95.62**	**Reliable**
Reliability of Posttest on Critical Thinking Skills				
Item number of Posttest on Critical Thinking Skills	**Modeling Class**		**Implementation Class**	
	Average of PA per Item (%)	**Category**	**Average of PA per Item (%)**	**Category**
1.	95.63	Reliable	93.67	Reliable
2.	95.51	Reliable	94.69	Reliable
3.	97.44	Reliable	97.49	Reliable

4.	97.09	Reliable	97.75	Reliable
5.	96.67	Reliable	94.85	Reliable
Quantity	**97.18**	**Reliable**	**96.26**	**Reliable**
Reliability of learning devices PhET simulation-assisted using PBL model	**96.66**	**Reliable**	**95.73**	**Reliable**
	96.20		**Reliable**	

Based on Table 4, we can observe that in general PBL learning device assisted by PhET simulations that have been developed by researchers composed of LKPD PBL and critical thinking skills test questions are reliable with a percentage of reliability of 96.205. Meanwhile, in detail, we can see empirical data on the level of reliability of LKPD PBL assisted by PhET simulation for the modeling class obtained a reliability percentage of 96.27% and 95.31% for the implementation class. The percentage of reliability for the pretest of critical thinking skills in the modeling class was 96.54% and 95.62% for the implementation class. Meanwhile, the percentage of reliability for pretesting critical thinking skills in the modeling class was 97.18% and 96.26%. The details of the data are all categorized as reliable because they meet the reliability requirements of the percentage of agreement (PA) value, where the research instrument in this case the PBL learning device assisted by the PhET simulation can be said to be reliable, if the percentage of agreement (PA) value obtained for each research instrument more than 75% (Borich, 1994).

Based on Table 4, we can observe that the results of the reliability of learning devices for the modeling class and implementation class in MAN 3 Sleman obtained different reliability results. In this case the level of reliability of PBL learning device with the assisted of PhET simulations for modeling class obtained higher reliability results than the reliability of the implementation class. Nevertheless, the reliability of PBL learning devices assisted by PhET simulations in both classes is at 90% intervals and all are included in the reliable category. This can happen, one of which is influenced by the assessors who provide the lowest and highest scores of diverse or many assessors. In addition, it can also be caused by the achievement of work on LKPD PBL assisted by PhET simulation and the results of critical thinking skills tests in the implementation class are lower than in the modeling class, so the percentage of reliability is also higher for the modeling class. This often happens because each assessor gives an assessment of each research instrument that has different views, there are times when the first rater gives the highest score on a particular item number,

but the other rater gives the lowest score on that item number (Yuliani & Saragih, 2015). Therefore, the percentage acquisition of reliability of each research instrument in the modeling class and the implementation class is also different, but still in the same interval.

The results of data analysis class X MIPA (modeling class and implementation class) at MAN 3 Sleman

In this data analysis section, we first discuss the physics learning activities of class X MIPA conducted by physics teachers at MAN 3 Sleman. Class X MIPA physics learning activities in MAN 3 Sleman are quite dense and the year-end assessment (PAT) implementation schedule is advanced, so teachers need to accelerate the explanation of all physics chapter in class X MIPA. Nevertheless, many students do not understand the physics chapter provided by the teacher with an explanation that is faster than usual. Finally, the solution of the physics class X MIPA teacher at MAN 3 Sleman is to explain the impulse and momentum chapter to students and the work and energy chapter with the energy sub-topic explained by the modeler or researcher in class X MIPA 1 for 2 hours or 90 minutes. Keep in mind the class X MIPA 1 at MAN 3 Sleman is used as a modeling class, which means that the class is stimulated with PBL learning tools assisted by PhET simulations and researchers are tasked with explaining work and energy chapter to students. Meanwhile, the solution made by the physics teacher in class X MIPA MAN 3 Sleman is to explain the chapter momentum and impulses to students first and the work and energy chapter with energy sub-points explained by the teacher in class X MIPA 3 for 2 hours or 90 minutes. Keep in mind class X MIPA 1 at MAN 3 Sleman is used as a modeling class, which means class stimulated with PBL learning tools assisted by PhET simulations and physics teachers are tasked with explaining work and energy chapter to students.

Like the research conducted by Savery (2015) which states that research activities in physics learning conducted by different instructors, both different in terms of delivering physics chapter to students or different in terms of the frequency of instructors' habit of delivering physics chapter to students will be able to detect or measuring students' understanding of physics concepts and being able to measure their level of adaptation and also their confidence in new and different situations. In addition, the implementation of physics learning with different instructors combined

with PBL models will be very obvious in measuring their critical thinking skills, this is because the two different instructors will certainly provide a basic understanding and apperception of different physical materials (Jonassen & Hung, 2015).

Meanwhile, the results of the implementation of research in two MIPA class at MAN 3 Sleman conducted by researchers/modelers and physics teachers are as follows. In carrying out research activities in slass X MIPA 1 in MAN 3 Sleman, which is used as a modeling class, there are some constraints in terms of the time allocation that has been planned in the lesson plan, but at the time the implementation was not according to the plan. The time allocation in the lesson plan (RPP) has been designed for 2 x 45 minutes, but the implementation of physics learning activities in class X MIPA 1 in MAN 3 Sleman as a modeling class held on Monday at 07.00 WIB until 08.30 WIB is not full 2 x 45 minutes because in the first 15 minutes used by students to read the holy book of the Qur'an. Meanwhile, the time allocation given by physics teacher class X MAN 3 Sleman for learning activities and posttest in modeling class was only on Monday, April 23, 2016 for 2 hours of learning, but the implementation was not full 2 x 45 minutes because in the first 15 minutes used by students to read the Qur'an.

Therefore, the time spent on learning physics and posttest activities in the modeling class is 75 minutes. For 45 minutes it is used for physics learning activities in the form of an explanation of skate board video games that are in accordance with the work and energy chapter, then students are guided by researchers/modelers to work on PBL LKPD using PhET simulation assistance. Meanwhile, the next 30 minutes are used to complete the posttest of critical thinking skills in the energy sub-topic. Learning activities in modeling class that experience a shortage of time that is not in accordance with the plans that have been prepared in the lesson plan. In the RPP that has been developed, the allotment of time for the implementation of learning activities in class X MIPA 1 in MAN 3 Sleman is 90 minutes, that time is used to explain learning videos to students, work on LKPD PBL, and also communicate each group about the results of the discussion they are in solving the physics problems given by the teacher and also the physical problems contained in the LKPD PBL assisted by the PhET simulation. Meanwhile, the plan to fill in the posttest critical thinking skills of students of class X MIPA 1 was not done right then after the learning activities were finished, but carried out at the next meeting before the explanation of the next chapter.

Meanwhile, research activities in the implementation class conducted by physics teacher class X MIPA 3 at MAN 3 Sleman experienced problems in presenting a PhET simulation by students. There are some groups of students who cannot use PhET simulations that have been shared by modelers on their cellphones or smartphones. This happens because the PhET simulation requires the Flash Player plugin on students' smartphones. If the student smartphone does not support Flash Player, the student smartphone cannot be used to operate the PhET simulation. So, the step taken by the teacher to overcome this problem is to ask the assisted of the modeler who was observing the course of learning by the teacher by lending a smartphone and laptop modeler to be used by students in operating the PhET simulation. This problem is in accordance with the statement Namgyel and Buaraphan (2017) which states that the PhET simulation can be operated in an offline model or without an internet signal, but requires devices such as smartphones and laptops that support the Flash Player plugin.

The feasibility of this research instrument in the form of PBL physics learning device assisted with PhET simulations on work and energy chapter in addition to being analyzed from validity and reliability, also their feasibility was analyzed based on students' responses to this research instrument. Specifically, the research instruments that were responded by students in this study were research instruments in the form of LKPD PBL assisted by PhET simulation and PhET simulation itself. This is because the two instruments are part of PBL learning device assisted by PhET simulations that function as a stimulus or treatment given by the modelers/researchers in this study. In addition, LKPD PBL and PhET simulation are also learning media for researchers' innovations which are the main physics learning media and as a substitute for media that are often used by physics class X MIPA teachers in MAN 3 Sleman which tend not to be student-centered. Therefore, the results of students' responses to the use of LKPD PBL assisted by the PhET simulation and the PhET simulation itself can be shown in Table 5 below.

Table 5. The results of students' responses to LKPD PBL and PhET simulation

No.	Item number of LKPD PBL Based on PhET Simulation	Modeling Class		Implementation Class	
		Validity of Each Aspect	Category	Validity of Each Aspect	Category

The students' responses to LKPD PBL assisted by PhET simulation					
1.	Display Aspect	0.70	Very Good	0.76	Very Good
2.	Aspects of Language	0.68	Very Good	0.63	Very Good
3.	Aspects of Critical Thinking Skills	0.72	Very Good	0.69	Very Good
	Quantity	**0.70**	**Very Good**	**0.70**	**Very Good**
The students' responses to simulation					
1.	Quality Content Aspects	0.77	Very Good	0.77	Very Good
2.	Aspect of Pleasure	0.73	Very Good	0.82	Very Good
3.	Aspects of Language	0.69	Very Good	0.75	Very Good
4.	Aspects of Learning Independencer	0.71	Very Good	0.73	Very Good
5.	Aspects of Use Illustration	0.78	Very Good	0.81	Very Good
	Quantity	**0.74**	**Very Good**	**0.78**	**Very Good**
The students' responses to LKPD PBL assisted by PhET simulation and PhET simulation		**0.72**	**Very Good**	**0.74**	**Very Good**
		0.73		**Very Good**	

Based on Table 5, in general the response of modeling and implementation class students at MAN 3 Sleman in physics learning activities using LKPD PBL assisted by PhET simulation and PhET simulation itself received very good responses with a score of 0.73. The details are the results of modeling class students' responses in physics learning activities using LKPD PBL assisted by PhET simulations obtained a very good response with a score of 0.70 and also obtained an excellent response in the implementation class with a score of 0.70. Meanwhile, the results of modeling class students' responses in physics learning activities using PhET simulations obtained a very good response with a score of 0.74 and also obtained an excellent response in the implementation class with a score of 0.78. Therefore, the results of modeling class students' responses in physics learning activities using LKPD PBL assisted by PhET simulation and PhET simulation itself obtained a very good response with a score of 0.72 and also obtained an excellent response in the implementation class with a score of 0.74.

Based on these results we can discuss that physics learning devices with PBL models that are assisted by PhET simulations developed by researchers get very good responses from students. That is because the learning media especially the PhET simulation has never been used by students in physics learning activities before. In addition, students can already compare various kinds of learning media that they often use, and PhET simulations that are more interesting, interactive, and easier to assist understand physics than other physics enhancing media that are often used by their physics teachers (Eichler & Peeples, 2016). Therefore, based on the results of the validity, reliability, and student responses to the physics learning device using the PBL model assisted by the PhET simulation, in general the learning device developed by the researcher is suitable for use in the physics learning activities of work chapters and energy in class X MIPA both at MAN 3 Sleman or at any high school whereever the characteristics of the students are similar to the characteristics of the class X MIPA students at MAN 3 Sleman.

After we find out the situation in the modeling class and the implementation class during the research activities, then we next discuss the results that have been obtained from the two classes of X MIPA in MAN 3 Sleman. The results that we discussed first are the results of LKPD PBL assisted PhET in the modeling class and the implementation class. After explaining the work and energy chapter through learning videos about skate board games to students in class X MIPA 1, students are asked by modelers/researchers to solve the problems contained in the LKPD PBL using the assisted of a PhET simulation that has been installed on a laptop or android smartphone. In addition, in class X MIPA 3 or implementation class, the teacher also explained the work and energy chapter through learning videos about skate board games to students. After that, students of class X MIPA 3 were also asked by their physics teacher to solve the problems contained in the LKPD PBL by using the assisted of a PhET simulation that was installed on an Android laptop or smartphone. The stimulus given by modelers/researchers and physics subject teachers in class X MIPA to students is to provide problems regarding skate board games that include learning videos and PhET simulations. It aims so that students better understand work and energy chapter. Meanwhile, the results of LKPD PBL work based on PhET simulations conducted by students of class X MIPA 1 as a modeling class and students of class X MIPA 3 as implementation class can be shown in Table 6 below.

Table 6. Results of working of LKPD PBL based on PhET simulation

Score	Modeling Class				Implementation Class			
	Score Each Aspect in LKPD PBL			Total Score LKPD PBL	Score Each Aspect in LKPD PBL			Total Score LKPD PBL
	1st PBL Aspect	2nd PBL Aspect	3rd PBL Aspect		1st PBL Aspect	2nd PBL Aspect	3rd PBL Aspect	
Quantity	128.00	164.40	264.00	1214.00	138.00	173.20	360.00	1364.00
Average	4.00	5.14	8.25	37.94	4.60	5.77	12.00	45.47
Minimal Score	0.00	1.40	0.00	19.00	3.00	3.60	12.00	41.00
Maximal Score	5.00	8.20	12.00	48.00	5.00	7.80	12.00	51.00
Achievement (%)	80.00	61.66	68.75	64.30	92.00	67.69	100.00	77.06
Category	**Good**	**Bad**	**Bad**	**Bad**	**Very Good**	**Bad**	**Very Good**	**Quiet Good**

Based on Table 6, for the modeling class and implementation class where PBL's 1st aspect of LKPD PBL is assisted by a PhET simulation that shows a syntax explanation about organizing students to learn, the 2nd aspect of PBL shows a syntax explanation of the development and presentation of the work/results of completion problems by students, and the third aspect of PBL shows the syntax about analyzing and evaluating the problem solving process that students do in groups. Based on the data in Table 8, it is easier for students in the modeling class and the implementation class to complete the items in the LKPD PBL based on the PhET simulation related to the 1st PBL syntax, which is about organizing students to learn. Meanwhile, students in both classes have difficulty in solving physics problems in LKPD PBL; assisted by PhET simulation related to the second PBL syntax, which is about developing and presenting their work/problem solving results. Meanwhile, student achievement in LKPD PBL assisted by PhET simulation is related to the 1st PBL syntax, which is about organizing students to learn reaching up to 80% for modeling class and 92% for implementation class. Student achievement in completing LKPD PBL assisted by PhET simulation is related to the second syntax, which is about developing and presenting work results or problem solving results obtained up to

61.66% and 67.695 for class implementation. Meanwhile, students' achievement in completing LKPD PBL was assisted by PhET simulation related to the 3rd syntax, which is about the analysis and evaluation of problem solving processes, reaching up to 68.75% and 100% for class implementation.

Based on these results, it can be discussed that in general, the two classes of X MIPA in MAN 3 Sleman, i.e the modeling class and the implementation class, have achieved almost the same aspects of PBL, i.e both classes are still weak in implementing the second aspects of the PBL model, i.e on the development and presentation of the results of problem solving. In addition, students in both of the class X MIPA are already good at organizing themselves to study physics. In general, students in class X MIPA are already proficient in organizing themselves to study physics, one of which is because these students do not experience significant difficulties in understanding apperception about problems in life about work and energy chapter provided by their modelers and teachers. This is very reasonable because the physics problems presented to students in the introduction to learning are simple problems and often involve students in the occurrence of these problems (Ernst *et al.*., 2017). In addition, the level of cognitive development of middle school students also supports the achievement of good results in the PBL aspect 1, because the level of cognitive development of middle school students is still classified as thinking towards the abstract (Karatas & Baki, 2017). However, students in the second class X MIPA began to experience obstacles when analyzing and developing solutions to more complex physics problems about work and energy chapter and they had never solved the problem before. This can happen because middle school students are also not accustomed to solving complex problems or a combination of various physical problems in a systematic and planned manner (Bachtiar, 2018). Meanwhile, the results of the subsequent data analysis are about the results of the students' pretest and posttest critical thinking skills in the modeling class and the implementation class, which are carried out before and after they study work and energy chapter with a PhET simulation. The results of the pretest and posttest critical thinking skills of students in the modeling class and the implementation class in MAN 3 Sleman can be observed in the following Figure 10.

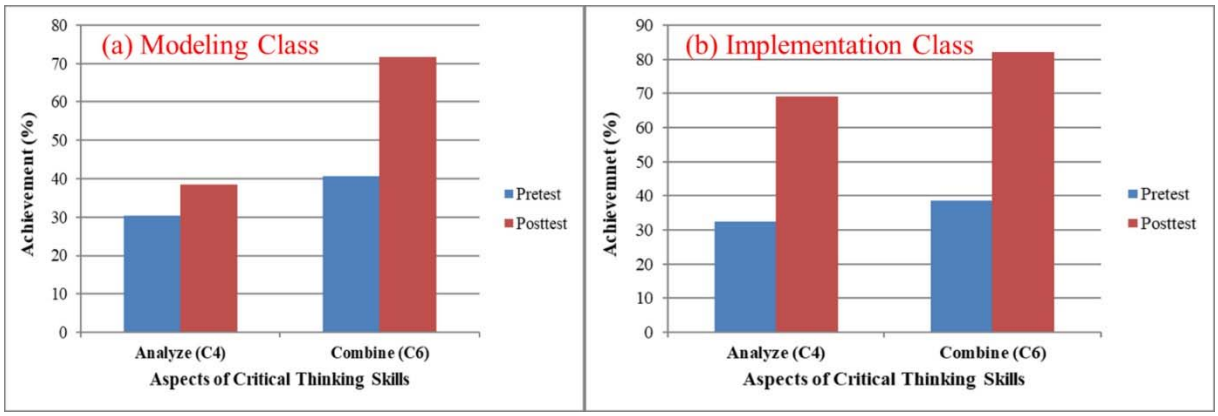


Figure 10. Results of pretest and posttest achievement of critical thinking skills, i.e in the (a) modelling class, and (b) implementation class

Based on Figure 10, which shows the results of pretest and posttest critical thinking skills of students in the modeling class and the implementation class shows that the level of critical thinking skills in the initial conditions in the modeling class is 35.97% which is included in the very bad category. However, the level of critical thinking skills of students in the initial conditions in the implementation class was 35.43% which was included in the less good category. However, after students study the work and energy chapters using the assisted of the PhET simulation and solve the problems regarding the work and energy chapters in the LKPD PBL assisted by the PhET simulation, the student learning outcomes achieved in the modeling class by 64.30% which are included in the less good category. In addition, the achievement of student learning outcomes in the implementation class after learning work and energy chapters with the assisted of PhET simulations and solving problems regarding work and energy chapters on LKPD PBL assisted by PhET simulations, the achievement of learning outcomes of 77.06% which is included in the quite good category.

However, the results of students 'critical thinking skills shown in the diagram in Figure 10 show that the results of students' critical thinking skills in the modeling class amounted to 59.81% which were included in the very poor category. The increase in critical thinking skills is indicated by the standard gain of 0.35 which is included in the medium category. Meanwhile, the results of students' critical thinking skills in the implementation class were 77.36% which were included in the quite good category. The increase in critical thinking skills as indicated by the standard gain value of 0.61 is included in the medium category.

Based on these results, students in the modeling class find it easier in the aspects of critical thinking skills about combining with an increase of 30.99% from the pretest and posttest results for the energy sub-topic. The results also apply to students in the implementation class, where students are easier in the aspects of critical thinking skills about combining with an increase of 43.62% of the results of the pretest and posttest for the energy sub-topic as well. This is caused by the cognitive development characteristics of middle school students who are at the formal operational stage who have many creative, innovative, and critical ideas (Asyari *et al.*., 2016). Therefore, it is easier for them to combine different things in the energy sub-topic well, because the cognitive level of students the class X MIPA in MAN 3 Sleman is more supportive of critical thinking skills on combining aspects than other aspects. However, students still find it difficult to analyze the problems in life about the work and energy chapters raised in the LKPD PBL with the assisted of a PhET simulation. In addition, these results also indicate some errors that occur during physics learning activities, one of which teachers still rarely provide variations in physics practice questions in addition to the calculation and tendency of physics learning is only centered on the teacher (Fuad *et al.*, 2017).

In general, students' critical thinking skills in modeling and implementation class have increased although not too large after they have learned the work and energy chapters with the assisted of PhET simulations. However, the results of critical thinking skills in the modeling and implementation class are different. It is very many factors that influence it, i.e the explanation of the work and energy chapters performed by two different instructors (physics teacher class X MIPA in MAN 3 Sleman who is used to chatting with students and also with modelers/researchers for the first time chatting with students of class X MIPA in MAN 3 Sleman). Another factor is the seriousness of students in paying attention to the explanation of the work and energy chapters explained by the two instructors. This is still a problem among high schools in Indonesia, where students tend to be indifferent or not care about the researchers who are researching them (Apino & Retnawati, 2017).

Most students often question whether what is done by researchers influences their final physics score or not, basically the high school students in Indonesia are still fixated on the value of the learning outcomes they get, not on the knowledge or competencies they have gained while participating in physics learning activities in class (Kong, 2015). In addition, the results of improving critical thinking skills in the

modeling class and implementation class in MAN 3 Sleman which are still relatively low are also in accordance with PISA data on the ranking of high-level thinking skills especially critical thinking skills of high school students in Indonesia which are still low (Tanujaya *et al.*., 2017). However, with the innovation in physics learning activities at MAN 3 Sleman using the assisted of the PhET simulation, students of class X MIPA become more enthusiastic and more challenged in studying other physics materials in detail. That is because the PhET simulation is a learning medium that is easy to operate and can be used at any time while having a smartphone, PC, or laptop (Widyastuti et al., 2019).

Furthermore, the next discussion is about the effectiveness of the use of PhET simulations in the physics learning work and energy chapters in the modeling class and implementation class in MAN 3 Sleman. As was previously known that to analyze the effectiveness of the use of this PhET simulation, we analyzed it using the one sample t-test technique with the assisted of the analysis program that is using the SPSS 21 program. Decision criteria used are Ho rejected if the value of sig. obtained through the SPSS program is less than the level of significance (α) (Liu & Yao, 2016). The reference used in the effectiveness test of the PhET simulation is 75, which is the minimum limitation criteria score (KKM) that must be achieved by students after attending physics learning using a PhET simulation in the work and energy chapter. The value of 75 becomes a reference to determine the effectiveness of the PhET simulation applied in physics learning activities in terms of improving students' critical thinking skills.

Meanwhile, the hypothesis used for the one sample t-test for the effectiveness of the use of PhET simulation in the modeling class and the implementation class at MAN 3 Sleman in terms of improving students' critical thinking skills is as follows. For modeling class, Ho: PhET simulations are not effective in terms of improving students' critical thinking skills in the modeling class and Ha: PhET simulations are effective in terms of improving students' critical thinking skills in modeling class. For implementation class, Ho: PhET simulations are not effective in terms of improving students' critical thinking skills in classroom implementation and Ha: PhET simulations are effective in terms of improving students' critical thinking skills in classroom implementation. Mathematically, the two hypotheses for the modeling class and the implementation class can be written as follows, Ho: $\mu \leq 75$ and Ha: $\mu > 75$. The results of one sample t-test on the effectiveness of using PhET simulations in the

work and energy chapters in the modeling class and implementation class in MAN 3 Sleman can be shown in the following Table 7.

Table 7. Results of one sample t-test analysis

Class	Test Value = 75					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Modeling Implementation	-15.370	31	.000	-29.5487	-33.4696	-25.6279
	-8.1	29	.000	-20.13	-25.228	-15.03

Based on Table 7, we can observe that the PhET simulation in the modeling class and implementation class in MAN 3 Sleman is effectively used to improve students' critical thinking skills in the physics learning activities of work and energy chapters. PhET simulation is effectively used in physics learning activities in the modeling class and implementation class in MAN 3 Sleman, due to the value of sig. (2-tailed) in Table 7 is obtained at 0.00 which amount is less than 0.05. Therefore, Ha for modeling class and implementation class is accepted or PhET simulation is effective in terms of improving students' critical thinking skills in modeling class and implementation class. The effectiveness of the use of PhET simulation in learning physics is also in accordance with the views of Radnai *et al.*. (2019) which states that with the assisted of simulation media or games like PhET in learning science especially mathematics and physics, the learning activities or explanation of physics and mathematics material to physics is more effective than other media and student learning outcomes are also better. In addition, the effectiveness of the use of PhET simulations in physics learning work chapters and energy is also due to the nature of PhET simulations which are more interactive, communicative, and certainly more interesting for students in learning physics material (Correia *et al.*, 2019). PhET simulation media is also one of the physics learning media that allows physics learning activities to be centered on students, so students can develop the concepts of physics they already know by solving critical physics problems with the assisted of the PhET simulation itself (Ekmekci & Gulacar, 2015).

Conclusion

Based on these results, it can be concluded that PBL learning devices assisted by PhET simulations developed meet the eligibility requirements for use in physics learning activities using PBL learning models to improve students' critical thinking skills in work and energy chapters. This is evidenced by the Aiken's V validity score, the results of the reliability, and the results of student responses. The most important instrument in this study in the form of an effective PhET simulation is used in physics learning activities that use PBL learning models in work chapters and energy to improve students' critical thinking. Meanwhile, the increase in students' critical thinking skills in MAN 3 Sleman in the modeling class and the implementation class was 23.84% and 41.9% respectively with the standard gain values of 0.35 and 0.61 which were included in the medium category. Therefore, with various advantages and disadvantages in the physics learning device using the PBL model with the assisted of the PhET simulation, the physics learning device can be used as a reference for subsequent research by considering the advantages and disadvantages that exist. The physics learning device can also be used by physics teachers in high school as a reference in the variation of physics learning implementation in high school.

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