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Development of Online-based Inquiry Learning Model to Improve 21st-Century Skills of Physics Students in Senior High School

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Abstract
In the technological disruption era, education goals have evolved to emphasize students to possess 21st-Century Skills. Learning model capable of accommodating these skills is a model that has a balance between a scientific approach and the use of technology. This research aims to develop a valid, practical, and effective Online-based Inquiry learning model to improve the 21st-Century Skills of physics students in senior high school. This research was research and development (R&D). The stages of model development consisted of preliminary research, prototyping phases, and assessment phases. The model was validated by five experts. Sixty tenth-grade students participated in the field test. The results showed that the validity of the model is on very high category. The practicality of the model is on very practical category. The average level of the students' 21st-Century Skills is 84.72, while the average N-Gain scores is 0.63. Based on these results, the model fulfills the valid, practical, and effective category for improving students' 21st-Century Skills and is expected to be an alternative reference to enhance the quality of physics learning and other fields of science.

Keywords: 21st-century skills, inquiry, learning model, online learning

INTRODUCTION

Physics is a science that is synonymous with observation and experiment. According to Urone et al. (2020), and Zais (1976), Leonardo da Vinci, Galileo, and Newton created physics science by performing observations and elaborations of reasoning on the universe as a project of investigation. Performing observations and elaborations of reasoning like a scientist have broad support in the research literature as the best way for students to gain a mature understanding of physics (Furtak & Penuel, 2019). This is also stated in the NGSS (standards of USA pedagogical practices in K-12 science instruction) that physics learning has to require students to engage and reflect on phenomena and the universe (Calmer, 2019). One of the methods that can enable students to perform these scientific practices is inquiry-based learning (Aditomo & Klieme, 2020; Bevins & Price, 2016; Burgin, 2020; Choy et al., 2016; NRC, 2013; Pedaste et al., 2015). The Republic of Indonesia Ministry of Education and Culture Regulation Number 22 of 2016 also suggests applying inquiry in physics learning. However, in the current technological disruption era, there are "new" skills that are highly in demand and need to be owned by students, while considering "old" educational praxis irrelevant (Ahonen & Kinnunen, 2015; Bernhardt, 2015; Boyaci & Atalay, 2016; Donovan et al., 2014; van Laar et al., 2017).

These skills are 21st-Century Skills, which are recognized as competency standards that need to be possessed by students to fulfill the demands of success in their work and future life (Asrizal et al., 2018; Ball et al., 2016; Binkley et al., 2012; Partnership for 21st Century, 2019). Learning in schools needs to be able to provide experiences and opportunities that stimulate students to possess these skills (Ahonen & Kinnunen, 2015; Bernhardt, 2015; Boyaci & Atalay, 2016; Donovan et al., 2014). In other words, physics subjects are responsible for organizing learning capable of improving students' 21st-Century Skills.

Several studies have been carried out to organize learning capable of improving the 21st-Century Skills of students, especially in Indonesia. On the Sinta Indonesia

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Contribution to the literature

- 21st-Century Skills are skills that include ICT literacy, hence their holistic development can be realized through the development of 4C skills (creativity, critical thinking, collaboration, and communication) in a digital context.
- The development of 21st-Century Skills for students optimally needs to be carried out through learning that has a balance between a scientific approach and the use of technology.
- The results showed that Online-based Inquiry is a valid, practical, and effective learning model in developing 21st-Century Skills of students in senior high school physics learning.

website, hundreds of studies funded by the Ministry of Research, Technology, and Higher Education related to 21st-Century learning trends have been published. However, irrespective of these numbers of publications, optimal results have not been obtained, especially in physics learning. This is because the solutions offered are not yet in a complete form of learning design, like a learning model. According to Gilbert & Justi (2016) and Reigeluth et al. (2016), the use of learning models optimizes the process of developing student competencies in accordance with the goals set. This is because it covers all aspects of learning that have internal consistency between its components, such as methods, teaching materials, media, and assessments in sync with each other (Arends, 2009; Joyce et al., 2016). Reputable articles related to physics learning in Indonesia published from 2012-2019 were dominated by the development of media, teaching materials, or other learning components (Nurhasanah et al., 2020). As a result, systematic activities in the classroom have not been carried out optimally.

Existing learning models developed in preliminary studies show relatively positive results, such as the development of blended learning (Dwianto et al., 2017), e-learning (Muliyati et al., 2019), Project-Based Learning based on STEM (Syukri et al., 2021), as well as discovery-inquiry (Tompo et al., 2016). However, these models are not enough to accommodate the 21st-Century Skills development needs of students in physics learning. Although these models effectively improve learning outcomes, they are unable to accommodate students in developing 21st-Century Skills integrated with ICT literacy. The PjBL model based on STEM and discovery-inquiry emphasizes on scientific approach without integrating ICT at the infusing or transforming level. Furthermore, the model based on blended learning and e-learning emphasizes integrating ICT in the transforming level without emphasizing the scientific approach. Therefore, these models do not optimally accommodate the development of 21st-Century Skills in physics learning. Based on the 21st-Century Skills framework as defined by AASL (2019), NRC (2013), and Partnership for 21st Century (2019), these skills include ICT literacy. Indicators for creativity, critical thinking, collaboration, and communication must be observed in a digital context (van Laar et al., 2020). The characteristic of this model is a learning model that configures ICT in each phase. Students are given opportunities to demonstrate creativity and critical thinking through the use of ICT tools. Classroom management strategies should promote communication and collaboration in two forms (in-person and online). Technology is used to reflect learning in the classroom (Donovan et al., 2014). In other words, learning capable of accommodating the development of 21st-Century Skills in physics learning has a balance between a scientific approach and the use of technology. Irrespective of the ability of digital technology to provide a variety of tools that make it easier for students to learn, direct interaction between teachers, students, and technology are inseparable in developing their overall abilities in the 21st Century (Ayvaz Tunç, 2017; Wang, 2008; Webb & Gibson, 2015).

This phenomenon shows that the learning model that only uses constructivist theory as the basis for its development is no longer relevant today. Similarly, according to Adnan & Anwar (2020), online learning is no better than conventional learning in developing countries because it requires large internet bandwidth to accommodate interactions between teachers and students and students with their peers. Furthermore, many factors, such as the availability of virtual laboratories, internet speed, and students' digital literacy levels, cannot be fulfilled optimally (Dhawan, 2020).

Therefore, based on these gaps, it is important to determine a learning model with a balance between a scientific approach and the use of technology as a learning model that combines elements of constructivism and connectivism. This solution is actualized through an ICT-integrated inquiry learning model at the infusing level.

RESEARCH PURPOSE

The purpose of this research is to develop a valid, practical, and effective Online-based Inquiry learning model capable of improving students' 21st-Century Skills. This learning model is expected to improve the quality of physics learning and provide a learning experience in accordance with the current era. Furthermore, this research is expected to act as an alternative reference to improve the quality of learning in other fields of science.

METHODOLOGY

Research Design

This research and development study aims to develop a valid, practical, and effective Online-based Inquiry learning model using the Plomp model. According to Plomp and Nieveen (2013), the steps of this development model are preliminary research, prototyping, and assessment phases. In preliminary research, a need and context analysis, literature review, and the development of a conceptual framework for the Online-based Inquiry learning model were conducted. Needs and context analysis consists of inquiry-based learning, student, curriculum, and material analyses. The preliminary research results were a state-of-the-art and conceptual framework design of Online-based Inquiry learning model. The product design of the Online-based Inquiry learning model is carried out in the prototyping phase, which consists of a model book, teacher e-book, student e-book, and 21st-Century Skills assessment instrument. The instruments used to assess development products are validated first using the validation instrument assessment sheet. After the instrument is declared valid by the experts, self-evaluation of the product is conducted. Subsequently, five experts in education science, physics learning media, physics education, educational technology, and the Indonesian language validated the product development. Validation referred to indicators of content, construct, and language validity assessment. After being declared valid, the product is evaluated through one-to-one, small group evaluation, and field test. Furthermore, a summative evaluation is carried out in the assessment phase to conclude whether the Online-based learning model is practical and effective in developing 21st-Century Skills.

Research Subjects

Field tests are carried out at senior high schools in two regencies/cities in Jambi Province, namely State Senior High Schools (SSHS) 1 Sungai Penuh, 3 Sungai Penuh, and 7 Kerinci. The three senior high schools are selected using a cluster random sampling technique based on the 2019 National Examination scores, and in the high, middle, and low categories. The subjects were tenth-grade students majoring in Mathematics and Natural Sciences and consisted of 20 students in each school.

Instruments and Data Analysis

The research instruments used to collect data were validity assessment, practicality assessment, and 21st-Century Skills assessment. The validity analysis uses a Likert scale. The calculation of the final value data from the validation results is carried out using the Aiken's V equation (Azwar, 2014), as follows:

$$V = \frac{\sum Scores\ from\ expert\ -\ The\ lowest\ score\ in\ the\ category}{[Number\ of\ categories\ (Number\ of\ experts\ -\ 1)]} \quad (1)$$

The validity level of the developed product is based on five categories, namely invalid (V≤ 0.00), low validity (0.001≤V≤0.400), moderate validity (0.401≤V≤0.600), high validity (0.601≤V≤ 0.800), and very high validity (0.801≤V≤1.000) (Arikunto, 2015).

Practicality data analysis was obtained from the questionnaire instrument for teacher and student responses to the learning model. The indicators included the ease of following the learning model, the usefulness in physics learning, the usability of e-books, and time allocation. The practicality analysis uses a Likert scale, which is calculated to determine the final value data from the practicality results using Equation 2.

$$P = \frac{Scores\ from\ rater}{Maximum\ Score} \times 100 \quad (2)$$

The practicality assessment is based on five categories, namely not practical (0≤P≤20), less practical (21≤P≤40), quite practical (41≤P≤60), practical (61≤P≤80), and very practical (81≤P≤100) (Riduwan, 2009).

The effectiveness analysis of the Online-based Inquiry learning model is obtained from the 21st-Century Skills assessment instrument, which includes performance and peer assessments. The 21st-Century Skills analysis in each sub-evaluation uses Equation 3.

$$N = \frac{Number\ of\ the\ student\ scores}{Maximum\ Score} \times 100 \quad (3)$$

The assessment is categorized based on five categories, namely very low (0≤N≤29), low (30≤N≤64), adequate (65≤N≤79), high (80≤N≤89), and very high (90≤N≤100). To measure the improvement of students' 21st-Century Skills, Gain analysis is used with Equation 4.

$$\langle g \rangle = \frac{\langle S_{post} \rangle - \langle S_{pre} \rangle}{100\% - \langle S_{pre} \rangle} \quad (4)$$

The improvement of students' 21st-Century Skills is assessed based on three categories, namely low (g<0.3), moderate (0.3<g<0.7), and high (g>0.7).

RESULTS AND DISCUSSION

The Conceptual Framework Design of the Online-based Inquiry Learning Model

The conceptual design of the Online-based Inquiry learning model is based on the results of a literature review on constructivism learning theory, connectivism learning theory, learning model theory, inquiry-based learning theory, integration of ICT in learning, and 21st-Century Skills framework. The design results are arranged into components of the learning model, as shown in Figure 1 and Figure 2.

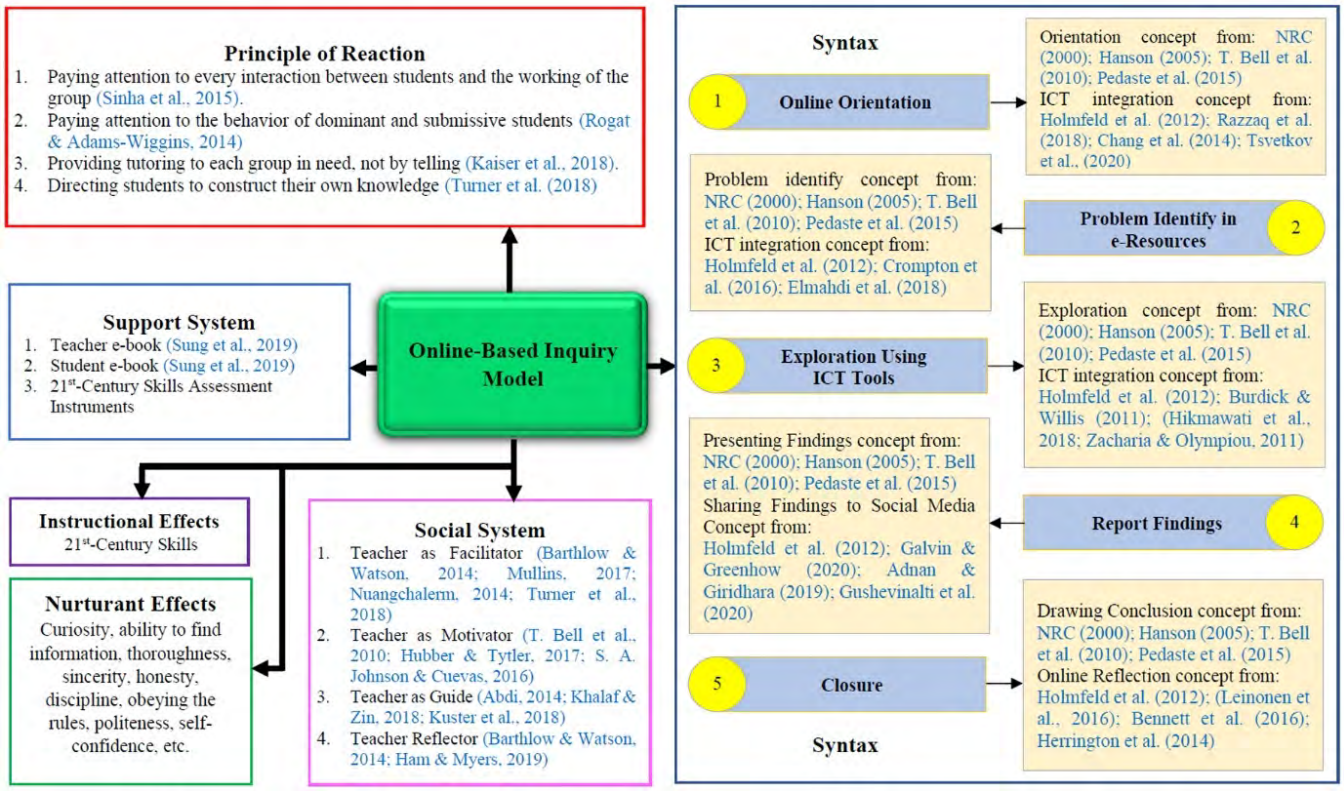

Figure 1. Conceptual design of online-based inquiry learning model

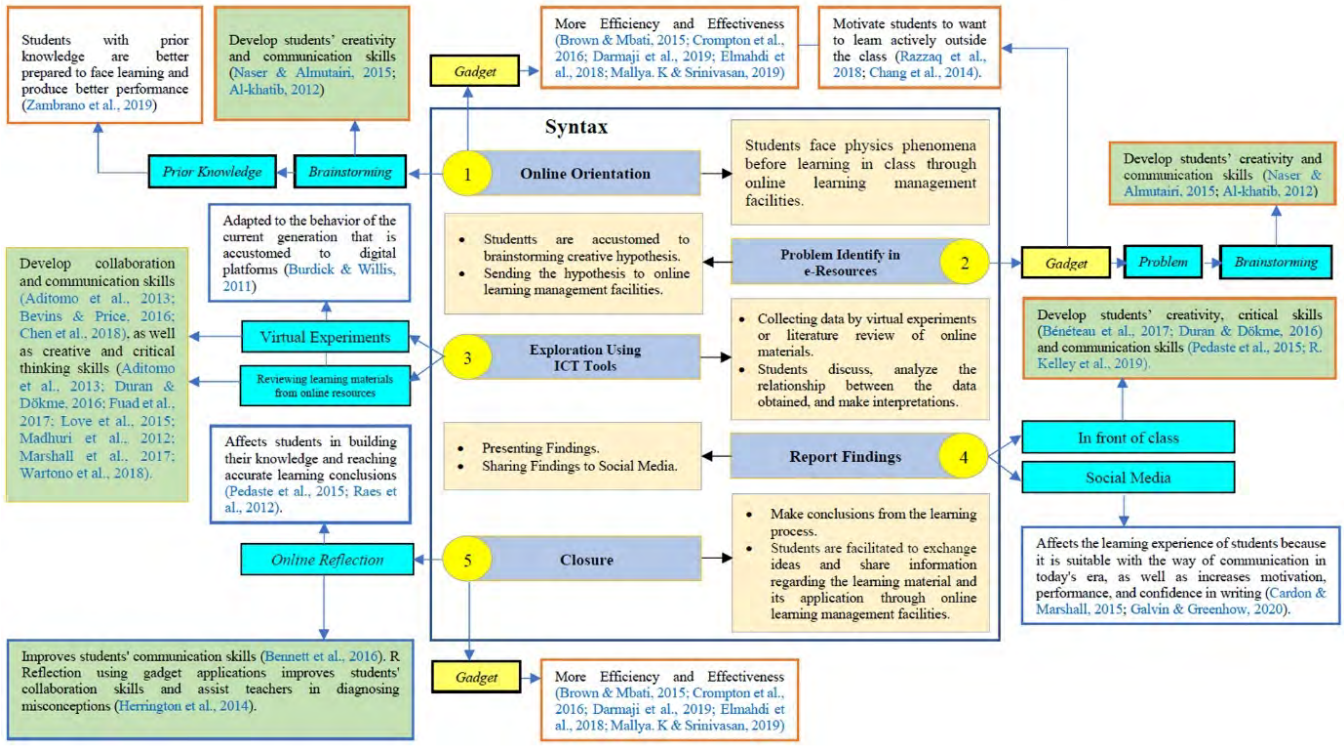

Figure 2. Scheme for the impact of learning model syntax on 21st-century skills

The position of the Online-based Inquiry learning model against other learning models and being state-of-the-art in this research can be seen in Table 1.

Table 1 shows that the novelty of the Online-based Inquiry learning model syntax is the integration of ICT that accommodates the activities of students in each phase. The aim is to train creativity, critical thinking, collaboration, and communication skills integrated with ICT literacy to students. Furthermore, it also aims to overcome the problem of learning hours in the classroom, which did not have the ability to accommodate all the steps of the inquiry-based learning model previously.

Table 1. Comparison of inquiry-based learning phases

NRC (2000)	Hanson (2005)	T. Bell et al. (2010)	Pedaste et al. (2015); Pedaste & Mitt (2020)	Online-based Inquiry
Oriented Questions: Questioning Problems	**Orientation:** Providing apperception and motivation to students, as well as conveying learning objectives	**Orientation:** Questioning Problems	**Orientation:** Stimulating students' curiosity on learning topics	**Online Orientation:** Facing a phenomenon to students before learning in the classroom through online learning management facilities.
Develop explanations that address scientifically oriented questions: Creating a hypothesis	**Exploration:** Presenting problems, formulating hypotheses, collecting data, testing hypotheses	**Hypothesis Generation**	**Conceptualization:** • Questioning • Hypothesis Generation	**Problem Identify in e-Resources:** • Questioning • Sending Hypotheses
Formulate explanations from evidence: Making an explanation by comparing the hypothesis with the exploration results.	**Concept Formation:** Building and presenting the concepts found.	**Planning:** Planning the exploration process	**Investigation** • Exploration: • Experimentation: • Data Interpretation:	**Exploration Using ICT Tools:** • Virtual Experiment or Reviewing learning materials from online resources • Analyzing Data • Explanations from Evidence
Evaluate explanations: Evaluating explanations	**Application:** Applying the built knowledge to other situations	**Investigation**	**Conclusion:** Making conclusions based on the comparison of hypotheses and experimental results	**Report Findings:** • Presenting Findings in Front of Class • Sharing Findings to Social Media
Communicate: Communicating inquiry results	**Closure:** Learning reflection	• Interpretation • Conclusion • Communication • Prediction: Applying the built knowledge by predicting the solution of the problem in other situations	**Discussion:** • Communication Presenting the findings • Reflection Evaluating the learning process by conducting discussions	**Closure:** • Drawing Conclusion • Online Reflection: Exchanging ideas, sharing information, and others regarding the learning materials studied and their application after learning through online learning management facilities.

In the first syntax (Online Orientation), students face physics phenomena that cause intellectual confrontation and trigger their ability to brainstorm the phenomenon and develop their creativity and thinking skills. According to Naser and Almutairi (2015), and Al-khatib (2012), brainstorming enables students to be accustomed to expressing their opinions orally and in writing, thereby enhancing their communication skills.

Another aim of this first syntax is to make students have prior knowledge on the strategies needed to deal with learning in the classroom. According to Zambrano et al. (2019), students with prior knowledge are better prepared to face learning and produce better performance. Furthermore, the effectiveness of collaborative learning is strongly influenced by prior knowledge in achieving learning objectives (Liu et al., 2014; Zhang et al., 2016).

This first stage is carried out through student gadgets before learning in class. In addition to considerations of efficiency and effectiveness (Brown & Mbati, 2015; Crompton et al., 2016; Darmaji et al., 2019; Elmahdi et al., 2018; Mallya. K & Srinivasan, 2019), the use of gadgets, such as e-books connected with the Google Classroom application motivates students to prepare themselves before learning. According to Razzaq et al. (2018), gadgets motivate students to want to learn actively outside the class because the self-efficacy of technology affects their self-regulation. Students' self-efficacy of technology is a factor that affects their performance and motivation in an online environment (Chang et al., 2014). This process is a cognitive and an apperception model that combines an information approach with cognitive methods to build complex mental readiness (Tsvetkov et al., 2020).

In the second syntax (Problem Identify in e-Resources), students are accustomed to brainstorming creative ideas to improve their communication skills. This is the initial stage of the core learning activities in the classroom. Furthermore, they are also faced with physics problems that aim to cause intellectual confrontation (confusion) and provide opportunities to formulate hypotheses. According to Bevins and Price (2016), Kabil (2015), and NRC (2013), problems in science learning, especially physics, are something that experts highly recommend. According to Psychologists Gestalt and Edward C. Tolman, when students are faced with problems, a state of cognitive disequilibrium appears and raises motivational elements (Hergenhahn & Olson, 2017). In other words, students are motivated to determine an insight on the solution to the problem. This second stage is also accommodated by the efficiency and effectiveness of students' gadgets (Brown & Mbati, 2015; Crompton et al., 2016; Darmaji et al., 2019; Elmahdi et al., 2018; Mallya. K & Srinivasan, 2019). Therefore, gadgets, such as e-books connected to the Google Classroom application, accommodate the formulation of hypotheses from all students.

In the third syntax (Exploration Using ICT Tools), students perform exploration related to the problems presented in the second syntax, which is accommodated by their gadgets. Data collection is carried out by virtual experiments when the material is abstract or difficult to be observed, such as analyzing the pattern of changes in velocity values constantly within a certain period, analyzing patterns of constant changes in velocity values in a vertical motion, setting force values to analyze the relationship between acceleration, mass, and force. Furthermore, the data were collected through reviewing learning materials from online resources when the material is factual and does not require procedural analysis, such as the notion of position, distance, displacement, speed, velocity, acceleration, and force.

The application of virtual experiments and reviewing learning materials from online resources is based on the characteristics of current students. According to Burdick and Willis (2011), the learning approach needs to be adapted to the behavior of the current generation that is accustomed to digital platforms. Furthermore, the application of virtual experiments in physics learning shows results that are as effective as the application of real experiments in enhancing students' knowledge, attitudes, and skills competencies (Hikmawati et al., 2018; Zacharia & Olympiou, 2011). The application of literature review is also very important because it is part of inquiry and affects students in building their knowledge and reaching accurate learning conclusions (Pedaste et al., 2015; Raes et al., 2012).

After collecting data, students discuss, analyze the relationship between the data obtained, and make interpretations. These activities train them to develop collaboration and communication skills (Aditomo et al., 2013; Bevins & Price, 2016; Boaventura et al., 2020; Chen et al., 2018), as well as creative and critical thinking skills (Aditomo et al., 2013; Duran & Dökme, 2016; Fuad et al., 2017; Love et al., 2015; Madhuri et al., 2012; Marshall et al., 2017; Wartono et al., 2018). This is because, in this exploration process, students are accustomed to exploring, concluding, and discussing information, then presenting the results with deductive or inductive explanations and formal communication styles.

In the fourth syntax (Report Findings), students are allowed to convey their findings by interpreting the data obtained in the exploration process with the formulated hypothesis. The delivery of these findings is carried out through class presentations and by sharing them on social media. Apart from being part of the inquiry process that develops students' scientific skills (Duran & Dökme, 2016; Love et al., 2015), presentations in front of the class helps to develop their critical, creative thinking (Bénéteau et al., 2017; Duran & Dökme, 2016) and communication skills (Pedaste et al., 2015; R. Kelley et al., 2019). Currently, it is not mandatory to distribute these findings in front of the class due to the emergence of social media. Scientific facts show that today's society is more interested in the information presented on social media (Galvin & Greenhow, 2020). This is important to use in education (Adnan & Giridharan, 2019) because it can prevent students from the habit of using social media for unimportant things (Hagler, 2013). Furthermore, it is important to note that the current form of communication is digital because it goes both ways (Gushevinalti et al., 2020), and it is more open and broader (Galvin & Greenhow, 2020; Hickerson & Kothari, 2017). The delivery of learning findings on social media is necessary to prepare students to have communication skills relevant today. According to Cardon & Marshall (2015) and Galvin & Greenhow (2020), the use of social media in learning affects the learning experience of students because it is suitable with the way of communication in today's era, as well as increases motivation, performance, and confidence in writing.

The last stage in the Online-based Inquiry learning model is the fifth syntax (Closure), which consists of two main activities. Firstly, the teacher and students make conclusions from the learning process for proper evaluation and conclusion (Bevins & Price, 2016; Pedaste et al., 2015). Secondly, after learning in class (online reflection), students are facilitated to exchange ideas and share information regarding the learning material and its application. This activity is carried out through student gadgets after learning due to the efficiency and effectiveness (Brown & Mbati, 2015; Crompton et al., 2016; Darmaji et al., 2019; Elmahdi et al., 2018; Mallya. K & Srinivasan, 2019), and motivation (Chang et al., 2014; Razzaq et al., 2018).

According to Leinonen et al. (2016), this activity is very important in learning using gadget applications

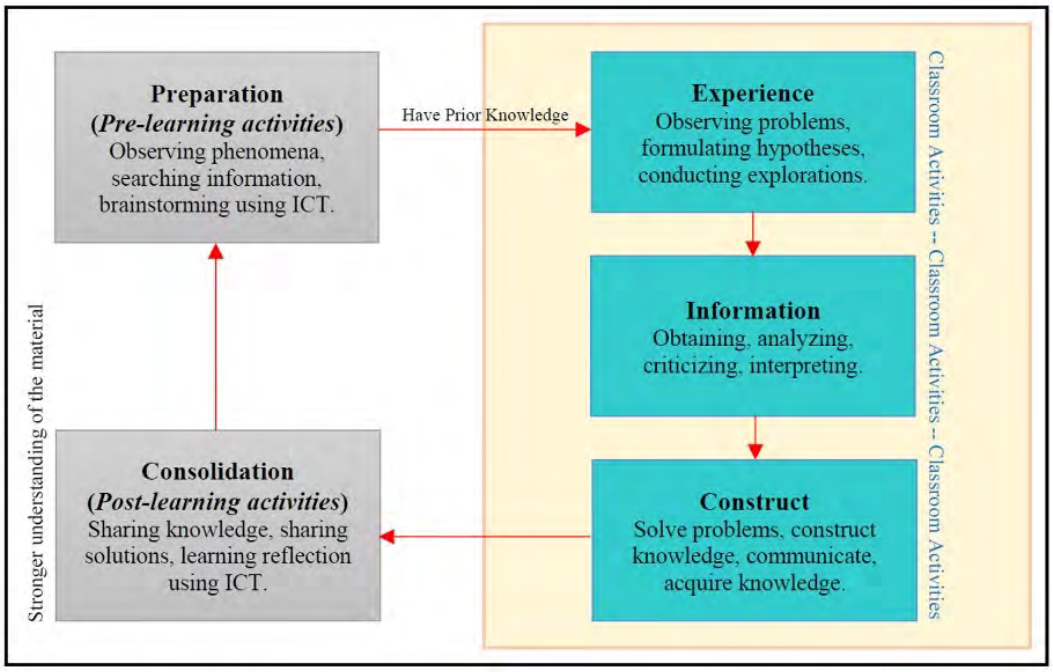

Figure 3. The basic cycle of online-based inquiry learning

because it provides benefits for students to ask questions, discuss, and work together in order to achieve a more complex level of knowledge outside the classroom. Reflection using gadget applications improves students' collaboration and communication skills (Bennett et al., 2016) and assists teachers in diagnosing misconceptions (Herrington et al., 2014). Moreover, student interaction level (discussion) in the digital group is higher than in the group without digital tools (Heindl, 2018). Therefore, this activity acts as a place for students to develop their creative and critical thinking, collaboration, and communication skills. The teacher also uses it as a tool for diagnosing misconceptions and determining the extent to which students develop learning materials.

This concept describes that the Online-based Inquiry learning model is an embodiment of learning that has a balance between a scientific approach and the use of technology to accommodate students in developing 21st-Century Skills and constructing their understanding through concrete and digital experiences. In its implementation, the Online-based Inquiry learning model phases are a cycle that includes preparation for prior knowledge, observing phenomena, gathering information, building and developing knowledge, as shown in Figure 3.

Online-based Inquiry learning has a systematic and comprehensive activity in discussing a lesson topic based on the process cycle. The existence of a preparation process to build students' prior knowledge provides better performance in the inquiry process in the classroom. Moreover, the existence of a reflection process after learning in class using online learning management facilities a more stable understanding of students. Furthermore, the Online-based Inquiry learning model also maximally involves students' thinking (creative, critical, systematic, analytical, and logical), scientific (scientific attitudes and skills), and social (communication and collaboration) abilities. Therefore, the process cycle of the Online-based Inquiry learning model is a solution to the development of students' 21st-Century Skills.

The Validity of the Online-based Inquiry Learning Model

The assessment included the validity of content, construct, and language. Product validation was carried out by five experts in written form and discussed until they agreed that the Online-based Inquiry learning model developed was valid, as shown in Table 2.

The Practicality of the Online-based Inquiry Learning Model

According to Plomp and Nieveen (2013), the practicality of the product developed (intervention) is seen from the ease of usage. The practicality of the Online-based Inquiry learning model is shown by the consistency between the typology of expectations with assessments and operations. This means that the practicality of the learning model is determined by the assessment of experts that stated that the product developed can be applied. In this case, it is known that the syntax, social system, and reaction principle of the Online-based Inquiry learning model according to the validators at the validation stage can be implemented with the average values of V at 0.83, 0.75, and 0.83, respectively. Furthermore, these results are compared with the teacher and student responses regarding the

Table 2. Product development validation results

Product	Component	Validity	
		Score (V)	Description
Model book	Construct	0.91	Very high
	Content	0.85	Very high
	Language	0.86	Very high
Teacher e-book	Construct	0.85	Very high
	Content	0.84	Very high
	Language	0.86	Very high
Student e-book	Construct	0.89	Very high
	Content	0.91	Very high
	Language	0.88	Very high
21st-Century Skills Assessment	Construct	0.94	Very high
	Content	0.88	Very high
	Language	0.77	Very high

Table 3. Practicality results according to teacher

Assessment Aspect	SSHS 1 SP	SSHS 3 SP	SSHS 7 KR
Teacher e-book			
The ease of applying teacher e-book in physics learning.	4	3.66	3.66
The usefulness of teacher e-book in physics learning.	3.60	3.80	3.80
The usability of teacher e-book in physics learning.	3.66	4	4
Average (%)	93.18	95.45	95.45
Overall Average (%)		94.70	
Category		Very Practical	
Student e-book			
The ease of following student e-book in physics learning.	4	3.66	3.66
The usefulness of student e-book in physics learning	3.83	4	3.83
The usability of student e-book in physics learning.	3.60	4	3.80
Time allocation for the application of student e-book in physics learning.	4	4	4
Average (%)	95.31	98.43	95.31
Overall Average (%)		96.35	
Category		Very Practical	

Table 4. Practicality results according to students

Assessment Aspect	SSHS 1 SP	SSHS 3 SP	SSHS 7 KR
The ease of following student e-book in physics learning.	3.23	3.06	3.31
The usefulness of student e-book in physics learning.	3.45	3.36	3.37
The usability of student e-book in physics learning.	3.47	3.44	3.44
Time allocation for the application of student e-book in physics learning.	3.65	3.56	3.51
Average (%)	86.71	84.45	85.46
Overall Average (%)		85.54	
Category		Very Practical	

practicality of the Online-based Inquiry learning model actualized by the application of the teacher and student e-books. The practicality results according to the teacher are shown in Table 3.

Table 3 shows that the Online-based Inquiry learning model actualized with the teacher and student e-books is practical and makes it easier for teachers to convey the material of straight motion and Newton's laws. The average percentage of teacher and student e-books is in the 80-100 intervals and in a very practical category. Respondents consider that the learning model makes learning activities more practical for teachers and students. The model practicality results according to students are shown in Table 4.

Table 4 shows that the Online-based Inquiry learning model actualized with student e-book help facilitate students in the learning process. The average percentage of the assessment is in the 80-100 intervals, in a very practical category and more practical for students.

The Effectiveness of the Online-based Inquiry Learning Model

According to Plomp and Nieveen (2013), the effectiveness of the developed product (intervention) is seen from the achievement level of an expected goal. This means that the Online-based Inquiry learning model is declared effective when it has the ability to develop students' 21st-Century Skills. The results of the field test stage obtained from the three schools and the

Table 5. 21st-century skills assessment results

State Senior High School (SSHS) 1 Sungai Penuh					
Observed aspects	Meeting				
	Pre-experiment	I	II	III	IV
Creativity	55.56	61.88	72.50	76.46	84.24
Critical thinking	49.91	54.31	66.99	73.80	82.18
Collaboration	70.93	77.13	82.59	85.00	87.96
Communication	63.98	71.02	74.93	79.19	84.12
Average	60.09	66.08	74.25	78.61	84.62
Category	Low	Adequate	Adequate	Adequate	High
State Senior High School (SSHS) 3 Sungai Penuh					
Observed aspects	Meeting				
	Pre-experiment	I	II	III	IV
Creativity	54.91	66.81	76.04	83.13	88.68
Critical thinking	47.22	60.79	68.33	76.25	77.45
Collaboration	72.87	77.13	81.02	86.76	90.00
Communication	62.50	72.36	78.15	82.52	86.69
Average	59.37	69.27	75.89	82.16	85.70
Category	Low	Adequate	Adequate	High	High
State Senior High School (SSHS) 7 Kerinci					
Observed aspects	Meeting				
	Pre-experiment	I	II	III	IV
Creativity	53.24	66.67	73.75	80.95	84.61
Critical thinking	45.46	57.82	63.43	72.22	78.94
Collaboration	70.74	70.46	75.00	85.19	88.61
Communication	61.94	67.57	72.45	80.35	83.17
Average	57.84	65.63	71.15	79.67	83.83
Category	Low	Adequate	Adequate	Adequate	High

Table 6. 21st-century skill N-gain score

School	N-Gain Score				Average
	Creativity	Critical Thinking	Collaboration	Communication	
SSHS 1 SP	0.65	0.62	0.64	0.56	0.62
SSHS 3 SP	0.74	0.55	0.69	0.64	0.65
SSHS 7 KR	0.67	0.60	0.63	0.56	0.61
Average	0.63				
Category	Moderate				

analysis of their improvement indicate that students experience an increase in each meeting, as shown in Table 5 and Table 6.

At the first meeting, the average scores of 21st-Century Skills at State Senior High Schools 1 Sungai Penuh, 3 Sungai Penuh, and 7 Kerinci are 66.08, 69.27, and 65.63, respectively. Sub-evaluations that are still classified in the low category are creative and critical thinking skills. However, the score of creative thinking skills at State Senior High Schools 3 Sungai Penuh and 7 Kerinci is in the adequate category of 66.81 and 66.67. In comparison, State Senior High School 1 Sungai Penuh is still relatively low at 61.88. This is because the mental readiness and self-confidence of students are still low in expressing their opinions. According to Chan (2013), an important factor for fluency in expressing opinions is self-confidence. The courage and confidence of students to express opinions depend on their mental readiness (Sullivan, 2015). These two factors are very important to make students able to express their opinions fluently.

Furthermore, the score of critical thinking skills at State Senior High Schools 1 Sungai Penuh, 3 Sungai Penuh, and 7 Kerinci are 54.31, 60.79, and 57.82, which are still in the low category. This is because of the previous class culture factors that accustom students to accept the opinions of others without discussions. According to Ghadi et al. (2012), and Facione and Gittens (2013), the culture of seeking truth, open-mindedness, confidence, and curiosity in the classroom are important factors that influence the development of students' critical thinking skills. In other words, poor teacher-student interaction (class culture) can constrain the implementation of dialogic learning (Worku & Alemu, 2021).

At the next meeting, the average scores of 21st-Century Skills at State Senior High Schools 1 Sungai Penuh, 3 Sungai Penuh, and 7 Kerinci are 74.25, 75.89, and 71.15 respectively. All sub-evaluations are in the adequate category, with none in the low category. This increase indicates that students are getting used to the Online-based Inquiry learning model. The complexity of the learning model, which is at the Guided Inquiry level,

also has a positive effect because Guided Inquiry can be used on students that do not have much learning experience with inquiry steps (Lazonder & Harmsen, 2016), and the teacher does not lose control to provide better learning experiences for students (Bodner & Elmas, 2021).

Creative and critical thinking skills, which were initially low at the first meeting, reached adequate category at this meeting. This indicates that the problem of the previous class culture that accustoms students to accept other people's opinions without the desire to determine and discuss the process can be overcome. This shows that gadgets in the first syntax motivate students to prepare themselves before learning. According to Razzaq et al. (2018), gadgets provide intrinsic motivation for students to learn outside the classroom actively. Therefore, students have prior knowledge to deal with learning in the classroom. Hence, they are more confident to argue and provide feedback on the opinions of their peers.

One sub-evaluation that reached a high category at this second meeting is collaboration. This achievement is in State Senior High School 1 Sungai Penuh and 3 Sungai Penuh, with scores of 82.59 and 81.02, respectively. Meanwhile, in the State Senior High School 7 Kerinci is still in the adequate category of 75.00. The achievement is due to the arrangement of activities in the Online-based Inquiry learning model that creates positive social interactions among students, such as collecting data, analyzing the relationship, and making interpretations for solving problems. This interaction creates a positive dependence between group members to rely on each other, leading to trust and responsibility (Kwon et al., 2013; Laal, 2013; Patel et al., 2012). Moreover, the prior knowledge factor makes their collaborative performance better (Zambrano et al., 2019).

In contrast to State Senior High School 1 Sungai Penuh and 3 Sungai Penuh, collaboration skills at State Senior High School 7 Kerinci have not yet reached the high category. This is because the teachers divided the groups based on the order of absent numbers, hence their composition was not heterogeneous. According to Lai (2011), teachers need to pay attention to group composition in terms of students' gender and ability level to make the application of group learning able to produce better student collaboration performance. However, gender did not significantly affect the collaboration performance of students (De Hei et al., 2015). This is proven in the State Senior High School 1 Sungai Penuh, where three non-heterogeneous groups showed good collaboration performance.

Furthermore, at the third and fourth meetings, the average score of 21st-Century Skills at State Senior High Schools 1 Sungai Full, 3 Sungai Penuh, and 7 Kerinci increased by 78.61, 82.16, and 79.67 at the third meeting and 84.62, 85.70, and 83.83 at the fourth. The results of the three schools are already in the high category. However, among the four sub-evaluations, students' critical thinking skills at State Senior High Schools 3 Sungai Penuh and 7 Kerinci are still in the adequate category with an average of 77.45 and 78.94 respectively. In terms of critical thinking skills sub-evaluation indicators, the ability to evaluate other people's arguments has the lowest score compared to other indicators, thereby affecting the average achievement of the sub-evaluation. This is because this indicator is very conditional where the ability to evaluate other people's arguments is only determined when there is a misconception among students. However, based on the improvement, critical thinking skills at State Senior High Schools 1 Sungai Penuh and 7 Kerinci have better N-Gain scores than communication skills. This indicates that Online-based Inquiry learning model is able to have a positive influence on the development of students' critical thinking skills.

The results obtained from four meetings at the three schools indicated that creative thinking and communication skill sub-evaluations do not show a significant anomaly. In all syntaxes, the Online-based Inquiry learning model accommodates the development of the two sub-evaluations. Students carry out brainstorming in the first and second syntax, which improves their creativity and communication skills (Al-khatib, 2012; Naser & Almutairi, 2015). In the third syntax, students collected data, analyzed the relationship, and made interpretations. These activities train them to develop communication skills (Aditomo et al., 2013; Bevins & Price, 2016; Chen et al., 2018) and creative thinking skills (Aditomo et al., 2013; Duran & Dökme, 2016; Fuad et al., 2017; Love et al., 2015; Madhuri et al., 2012; Marshall et al., 2017; Wartono et al., 2018).

In the fourth syntax, students conveyed their findings through classroom presentations to develop critical and creative thinking (Bénéteau et al., 2017; Duran & Dökme, 2016) and communication skills (Pedaste et al., 2015; R. Kelley et al., 2019). Furthermore, in the fifth syntax, online reflection provided an opportunity for students to ask questions and express opinions. This activity improves their communication (Bennett et al., 2016) and creative thinking skills (Duran & Dökme, 2016).

Overall, the four sub-evaluations of students' 21st-Century Skills experience a significant increase with N-Gain scores above 0.50 in the three schools. The average N-Gain scores at State Senior High Schools 1 Sungai Penuh, 3 Sungai Penuh, and 7 Kerinci are 0.62, 0.65, and 0.61, respectively, and in the moderate category. These results indicate that the Online-based Inquiry learning model improves students' 21st-Century Skills and fulfills the third intervention quality criteria as an effective learning model.

LIMITATIONS

Although the present Online-based Inquiry learning model seems effective, there are several limitations to this research. First, the sample size was not large. To better understand the effect of the model, large-scale experiments are needed in future research. Future research also needs to examine more deeply the effect of the Online-based Inquiry learning model at all levels of education, namely elementary, junior high school, and college levels. Second, the effectiveness assessment did not control for factors outside the research variables, such as physical condition, intelligence, and background of students, and teacher competence. Analysis of Covariance (ANCOVA) is needed to assess its effectiveness in future research.

IMPLICATIONS

The findings contribute to teachers' practice in designing lessons capable of improving students' 21st-Century Skills in physics learning and other fields of science and become an option for promoting learning in accordance with the students' characteristics (digital native) and trends 21st-Century learning. This research provides evidence that a model that has a balance between the scientific approach and the use of technology is relevant model to be applied today, especially in the New Normal COVID-19 era in Indonesia, and being a bridge to the digitalization of Indonesian education in the future.

CONCLUSION

In conclusion, the Online-based Inquiry learning model has a high quality in terms of validity, practicality, and effectiveness. The validity results of model book, teacher e-book, student e-book, and 21st-Century Skills assessment are in very high validity criteria in terms of content, construct, and language. This means that the learning model has fulfilled the criteria of relevance and consistency. According to teachers and students, the use of Online-based Inquiry learning model fulfills the criteria of ease, usefulness, and usability. In terms of effectiveness, the learning model is able to improve the 21st-Century Skills of students with an average N-Gain score of 0.63. In other words, Online-based Inquiry learning model has a significant influence on the development of students' 21st-Century Skills. Therefore, it can be used by physics teachers and those in other science fields to improve the quality of learning and developing students' 21st-Century Skills.

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APPENDIX 1

21st-Century Skills Assessment Instrument Indicators

Aspect	Indicator
Creativity	1. Generate ideas clearly (both in-person and online)
	2. Generate original ideas (both in-person and online)
	3. Respond the problems with many alternative solution (both in-person and online)
	4. Find sources of information to solve problems (both in-person and online)
	5. Implement existing knowledge in solving a problem
	6. Create new and unique product
Critical Thinking	1. Recognize the limitations of self and group
	2. Evaluate someone's argument (both in-person and online)
	3. Provide feedback on someone's arguments (both in-person and online)
	4. Delivering explanations (both in-person and online).
	5. Summarizing the quality of information (both in-person and online)
	6. Understand how to use knowledge from one situation to another
	7. Understand the questions asked by others (both in-person and online)
	8. Asking questions to clarify (both in-person and online)
	9. Interpreting information (both in-person and online)
Collaboration	1. Divide the work of group members fairly
	2. Helping groups solve problems (both in-person and online)
	3. Provide useful feedback for team members (both in-person and online)
	4. Review team progress in completing tasks (both in-person and online)
	5. Help solve problems without asking the teacher for help
	6. Recognize and respect the opinions of group members
	7. Act according to their respective roles
	8. Be polite and kind to teammates (both in-person and online)
	9. Able to deliberation in groups for decision making (both in-person and online)
	10. Use time efficiently
	11. Discuss completing tasks (both in-person and online)
	12. Offer help to others when needed
	13. Complete tasks without having to be reminded
Communication	1. Using appropriate media tools to increase knowledge (both in-person and online)
	2. Using a formal communication style (both in-person and online)
	3. Listening actively when other people are talking (both in-person and online)
	4. Present all information clearly, concisely, and logically (both in-person and online)
	5. Use formal body language when presenting
	6. Answering questions clearly and concisely (both in-person and online)

(Adapted from: Partnership for 21st Century (2019) and R. Kelley et al. (2019)

APPENDIX 2

Indicators of the Validity of the Online-based Inquiry Learning Model

Variable	Indicator	Description
Rationale	Background	The background of the development of the Online-based Inquiry learning model.
	Urgency	The urgency of developing the Online-based Inquiry learning model.
	Purpose	The purpose of developing the Online-based Inquiry learning model.
	Relevant supporting theory	Supporting theories relevant to the development of the Online-based Inquiry learning model.
Theoretical Basis	Covers cognitive learning theory	Optimizing the ability of rational aspects in forming hypotheses, testing hypotheses, and drawing conclusions.
	Covers constructivist learning theory	Covers discovery, problem solving, and collaboration processes.
	Based on the theoretical rationale of the information processing model group (The Information Processing Family)	According to Joyce et al., (2016), provide stimulation from the environment to students to be able to organize data, formulate problems, build concepts and plan problem solving, and use verbal and nonverbal symbols.
	Contains inquiry-based learning components	Contains inquiry-based learning components, namely: observing; formulate questions or hypothesize; collect information through books and other sources of information critically or carry out experiments or experiments; Analyze and interpret data.
	Based on the theoretical rationale of networked learning	According to Holmfeld et al. (2012), accommodate students in activities, such as: digital collaboration and digital communication; discussion and dialogue in groups; self-assessment in the learning process; access to digital learning resources; and scientific measures.
	Use of ICT in Infusing level	Student-centered and collaborative; ICT as a subject that cannot be separated from learning; Provides dispersed access to various digital resources; ICT-based assessment, student-centered, and using several types of assessment.
Syntax	Syntax order	Each phase of the Online-based Inquiry learning model is a logical sequence of learning activities.
	Syntax purpose	Each phase of the Online-based Inquiry learning model has a clear goal.
	Syntax organization	Each phase of the Online-based Inquiry learning model has a clear organization of activities.
	Teacher activities	Each phase of the Online-based Inquiry learning model contains the teacher's activities clearly.
	Student activities	Each phase of the Online-based Inquiry learning model contains the activities of students clearly.
	Support the achievement of learning objectives	Each stage of the Online-based Inquiry learning model supports the achievement of learning objectives.
	Integrating ICT	Each phase of the Online-based Inquiry learning model is integrated with ICT.
	Practicality	Each phase of the Online-based Inquiry learning model can be implemented.
	Accommodating the development of 21st-Century Skills	Each phase of the Online-based Inquiry learning model accommodates the development of 21st-Century Skills.
Social System	The relationship between teachers and students	Shows the pattern of the relationship between teachers and students clearly.
	Student activity	Individual activities are described clearly.
		Group activities are described clearly.
	Teacher activity	Teacher activities in each phase of the Online-based Inquiry learning model are described clearly
	Implementation	The social system in the Online-based Inquiry learning model has a good level of implementation.
	Supports syntax	The social system in the Online-based Inquiry learning model supports syntax implementation..
	Has a relationship with other model components	The social system in the Online-based Inquiry learning model has links with other model components.

Variable	Indicator	Description
Principle of Reaction	Teacher behavior	The teacher's behavior in each session of the Online-based Inquiry learning model is described clearly.
	Teacher's reaction	The teacher's reaction as a facilitator is described clearly.
		The teacher's reaction as a motivator is described clearly.
		The teacher's reaction as a supervisor is described clearly.
	Implementation	The principle of reaction in the Online-based Inquiry learning model supports the implementation of the syntax.
	Supports syntax implementation	The reaction principle in the Online-based Inquiry learning model supports the implementation of the syntax.
	Has a relationship with other model components	The reaction principle in the Online-based Inquiry learning model is related to other model components.
Support System	Support the implementation of learning	Teacher Book supports the implementation of learning in accordance with the Online-based Inquiry learning model.
		Student Book supports the implementation of learning in accordance with the Online-based Inquiry learning model.
	Has a relationship with other model components	The support system in the Online-based Inquiry learning model has links with other model components.
Instructional effect and nurturant effect	Scope	Each phase of the Online-based Inquiry learning model covers instructional effect and nurturant effect.
		The types of instructional effect and nurturant effect are described clearly.
		The types of instructional effect and nurturant effect are quite logical.
	Achievement of learning objectives	The types of instructional effect and nurturant effect describe the achievement of learning objectives.

APPENDIX 3

Indicators of Student E-book Practicality Instruments

Indicator	Sub-Indicator	Description
Implementation	The instructions are easy to understand.	Instructions for using the student e-book are easy to understand.
	Easy to use with a laptop or smartphone.	There are no obstacles in using the student e-book with a laptop or smartphone.
	Worksheets are easy to implement.	Worksheets in the student e-books are easy to implement.
Usefulness	E-book connectivity provides usefulness in obtaining information.	The connectivity of the student e-book (connected to learning management facilities/Google Classroom) make it easier for students to obtain the information needed to study learning materials.
	E-book connectivity provides benefits in communication and collaboration.	The connectivity of the student e-book (connected to learning management facilities/Google Classroom) make it easier for students tocommunicate and collaborate.
	Generate motivation and curiosity	The problems in the student e-book raise motivation and curiosity in studying learning materials.
	Forming an understanding of the learning material..	The learning steps in the student e-book make it easier for students to construct an understanding of the material.
	A clear description of the material.	The description of the material in the student e-book is easy to understand.
	Meeting current needs	The student e-books can be used as teaching material books that are relevant to the needs of the current era.
Applicability in physics learning	Generating interest in studying physics.	The student e-book keeps readers interested to participate in a physics lesson.
	Makes it fun to study physics.	The student e-book keeps readers comfortable to read the content.
	Easy to use for physics lesson.	The student e-book is easy to use in a physics lesson.
	Easy to observe physics phenomena.	The student e-book make it easier for students to observe physics phenomena.
	Help in constructing knowledge.	The student e-book is very helpful for students in constructing their knowledge.
Time Allocation	One lesson can be carried out within two hours of lessons.	One lesson in the student e-books can be carried out in two hours of lessons.
		Students are not in a hurry to participate in the lesson

APPENDIX 4

Indicators of Teacher E-book Practicality Instruments

Indicator	Sub-Indicator	Description
Implementation	The instructions are easy to understand	The teacher e-book makes it easy for teachers to get a conceptual framework about learning goals (includes the domains of attitudes, knowledge, and skills).
	Implementation.	The teacher e-book facilitating teachers in applying the Online-based Inquiry learning model.
	Provides convenience in managing learning.	The teacher e-book facilitates teachers in managing learning using learning management tools.
Usefulness	Giving guidance to the teacher.	The teacher e-book guides teachers in the selection of relevant media, tools, and learning resources.
		The teacher e-book guides the teacher in the selection of techniques and forms of instruments that will be carried out at each meeting.
		The teacher e-book guides teachers in conducting assessments in each domain of competence.
		The teacher e-book guides teachers in assessing the improvement of 21st-Century Skills
	Compatibility with the student e-book.	The teacher e-book has compatibility with the student e-book.
Keterpakaian dalam pembelajaran fisika	Relevant	The material presented in the teacher e-book is relevant.
		Learning tools and materials in the teacher e-book are easily available.
	Assessment rubric	The assessment indicators in the scoring rubric are clear and easy to observe.