ATOMIC PHYSICS TEACHING MATERIALS IN BLENDED LEARNING TO IMPROVE SELF-DIRECTED LEARNING SKILLS IN DISTANCE EDUCATION

Dr. Nia ERLINA

ORCID: 0000-0003-2199-5046
Department of Physics and Science Education
Universitas Pendidikan Ganesha
Singaraja, INDONESIA

Dr. PRAYEKTI

ORCID: 0000-0003-3527-4100
Department of Physics Education
Universitas Terbuka
Jakarta, INDONESIA

Dr. Iwan WICAKSONO

ORCID: 0000-0003-0717-1577
Department of Science Education
Universitas Jember
Jember, INDONESIA

Received: 31/12/2020 **Accepted:** 16/07/2021

ABSTRACT

Atomic physics teaching materials support student motivation to learn independently, guide, and direct students to master material with abstract characteristics. The teaching materials in blended learning can improve the tutorial system's interaction process in distance education with special characteristics. Universitas Terbuka students have various ages, professions, geographic location, social environment, and prior knowledge. This study aimed at analyzing the practicality and effectiveness of atomic physics teaching materials in blended learning to improve students' self-directed learning skills in the open and distance education system. This research involving 121 students spread across 12 regional offices in Indonesia. Analysis of the impact and consistency of students' self-directed learning skills used inferential statistics, then for data analysis, the improvement used N-gain. The results of the study showed the average tutorial feasibility using atomic physics teaching materials is the most dominant in explaining the teaching material thoroughly and is easy to understand. The average percentage of student activity results get the highest score on the activity of conducting discussions. The effectiveness analysis results showed the atomic physics teaching materials are proven to be effective in increasing students' self-directed learning. ANOVA obtained no significant difference from all test classes so that atomic physics teaching materials are effective for application to students who have low, medium, and high abilities. The process of practicality and effectiveness has implications for developing teaching materials for distance education systems that must pay attention to the tutorial process, learning management system, and several other components.

Keywords: Atomic physics, blended learning, distance education, self-directed learning skills.

INTRODUCTION

The distance education system has been widely used to expand access for people to obtain an education. The distance education system is an alternative institution for people to participate in educational programs due to scarcity of resources and the high cost of taking part in regular education programs (Kaye & Rumble, 2018). The Universitas Terbuka (UT) provides distance education system services to community groups who cannot attend face-to-face or regular education in various forms, modes, and coverage supported by learning facilities and services as well as an assessment system that ensures the quality of graduates is following the national standards of Indonesian education (Budïastra, Wïcaksono, & Erlina, 2020). Teaching materials and information technology used in the form of a distance education system make it possible to conduct lectures remotely without being tied to distance, wherever and whenever they can access this learning (Richter & McPherson, 2012). The distance education system requires students to study independently using a variety of teaching materials and learning assistance services. Self-directed learning in the context of this system impacts the use of information and communication technology, meaning that various media can be used as teaching materials (Wicaksono et al., 2017). In this distance education, the teaching materials used must be more varied when compared to face-to-face education.

Teaching materials are an important requirement in the lecture process, especially to achieve the set instructional goals. One of the challenges faced by the distance education system is how students can achieve maximum competence (Butcher, 2015). It is because students are physically separated from lecturers and other students, learning material plays an important role in replacing an instructor's presence in the learning process. Good distance teaching materials need to pay attention to the learning process itself, namely how the teaching material can provide clear and communicative instructions, considering that students are not directly accompanied by tutors in the learning process (Perraton, 2012). In fact, there are still many weaknesses in the tutorial process, especially in atomic physics material. The teaching materials presented use symbols that are difficult for students to understand. The questions in atomic physics teaching materials still do not encourage high-level thinking and it is not facilitate students to achieve instructional goals (Maftei & Popescu, 2012). Students often experience difficulties in understanding the meaning of the reading material presented because atomic physics characteristics are abstract and students cannot directly observe atoms. This fact makes it difficult for students to understand the concept of atomic physics as a whole. Atomic physics teaching materials provide less feedback for the questions it asks, especially questions that have many answers or require complex and deep answers (Endres et al., 2016).

The availability of varied and high-quality teaching materials is essential to be considered, especially to independently help students in the learning process. Independence is related to systematic and complete teaching materials, which can be studied independently to benefit the student lecture process in the distance education system (Berg, 2020). Teaching material needs are descriptions and important components such as clearly stating instructional objectives, examples, exercises, summaries, formative tests, feedback, and learning instructions (Kaye & Rumble, 2018). The development of atomic physics teaching materials encourages the presentation of learning material appropriately even though physically they are not in the same place. The teaching materials provide space for applying distance education techniques in the teaching materials easily accepted by students. Atomic physics teaching materials motivate students to study independently, guide and direct them to master the material and provide clear concepts through various independent exercises. Besides, atomic physics teaching materials are integrated with audio-visual media, which is very suitable for explaining abstract atomic physics material for students. Illustration in audio-visual media is designed so that it is easy to accept, attractive, and not boring for students (Zazkis et al., 2009).

Learning independence demands a great deal of responsibility on students, so that it requires effort to carry out various activities to achieve instructional goals. Independence is students' behavior in realizing their wishes or desires in a real way without depending on others. In this case, the student can do learning on their own, determine effective learning methods, carry out learning tasks well, and carry out learning activities (Perraton, 2012). Self-directed learning, in many ways, is determined by the ability to learn effectively. Self-directed learning indicators that students must have include: initiation and persistence in learning, responsibility, discipline and great curiosity, confidence and a strong desire to learn, and organizing learning time and speed (Broad, 2006). Learning ability depends on reading speed and the ability to understand the content of the reading. Self-directed learning becomes effective when UT students must have self-discipline, initiative, and strong learning motivation (Wechsler et al., 2018). Students are also required to manage their time efficiently so that they can study regularly based on their own study schedule.

Self-directed learning skills are abilities that are formed from an effective distance education process (Budiastra, et al., 2020). Indonesian government regulation, Permenristekdikti No. 51/2018 states that distance education is a teaching and learning process carried out remotely through the use of various communication media. Learning that supports various learning media is blended learning. Blended learning refers to a mixture of instructor-led and technology-based learning that is flexible. Blended learning describes an opportunity that integrates technological innovation and advantages in online learning with the interaction and participation of face-to-face learning benefits (Clark & Post, 2021). The basic concept of blended learning also optimizes oral communication in face-to-face learning with written communication in online learning. This learning can provide motivation and better learning outcomes than other methods, especially indirect learning methods (Agaoglu & Demïr, 2020).

Previous research shows that blended learning is used to properly combine Synchronous and Asynchronous learning settings (Li et al. 2020). This research was conducted at UT with an online learning system that is robust and effectively supports the Asynchronous learning setting. The distance education system requires students to be independent in learning to achieve goals. However, students' ability to study independently in the distance education system is generally still weak, so it requires a proper learning model (Pandiangan et al., 2017). Distance education is prone to controlling the learning process, so it is necessary to strengthen the interaction process between students, tutors, and technology (Budïastra et al., 2020). The interaction process needs to be raised through media and teaching materials to bring students to abstract thinking skills (Erlina et al., 2018). Students can use atomic physics teaching materials flexibly in terms of time and place. Furthermore, seen from its function as material supporting material integrated with printed teaching materials, it provides a meaningful learning experience. The development of a new generation of atomic physics teaching materials and appropriate technology for tutors and students in communicating is important (Butcher, 2015). Interaction is said to be effective if students are active in self-directed learning, and the tutor provides feedback to evaluate the lecture process that has been carried out. Evaluations designed in atomic physics teaching materials are complemented by the feedback that appears when students give inappropriate answers (Atenas & Havemann, 2013). Therefore, in addition to material selection, the use of teaching materials, the proper evaluation process will affect student success in achieving instructional goals.

STATEMENT OF THE PROBLEM AND QUESTION OF RESEARCH

The student's need for flexible learning continues to increase, especially for those constrained by time and place (Evans et al. 2020). The Universitas Terbuka (UT) engagement of blended learning tools in a management course includes a combination of e-learning, distance learning, and face to face learning. Blended learning is relevant for improving students who study while working, are in remote areas, and cannot directly learn fully face-to-face. UT students still need further study of student self-directed learning skills, so they need clear physics instruction (Pandiangan et al., 2017). Conventional university teaching of physics has shown little improvement in teaching physics principles. The domain of atomic physics is considered a difficult field to study because it deals with abstract and difficult to understand concepts (Maftei & Popescu, 2012). Thus the media and teaching materials for learning atomic physics are still challenging to develop. Further research shows that video-based learning can support learning interactions and a flexible learning system (Budiastra et al., 2019). This study aims to analyze how the practicality and effectiveness of atomic physics teaching materials improve students' self-directed learning skills in the distance education system. The research was conducted to answer the following questions: (1) what is the practicality which includes implementation in lectures, student activities, and the constraints that arise with atomic physics teaching materials to improve students' self-directed learning skills in the distance education system ?; and (2) what the effectiveness which includes increasing student self-directed learning skills and student responses to atomic physics teaching materials in blended learning to improve students' self-directed learning skills is?

METHOD

This research is Research and Development (R&D) namely Educational Research (Gall et al., 2003). The development carried out is in the form of new learning and supporting tools. This development procedure consists of two objectives, namely developing and testing atomic physics teaching material products through blended learning in achieving the goal of improving students' self-directed learning skills. Educational development research steps carried out for product design meet eligibility standards include: (1) research and information colletion, namely needs analysis, literature study; (2) planning, formulating research problems; (3) develop preliminary form of product, development of learning materials, learning process and evaluation instruments; (4) preliminary field testing, initial field testing of the design of teaching materials products; (5) main product revision, improvement of teaching materials based on limited field testing; (6) playing field testing, testing the practicality and effectiveness of teaching materials; (7) operational product revision, improvement of teaching materials based on input and main field test results; (8) operational field testing, practicality and effectiveness of teaching materials for prospective users; (9) final product revision, improvement of the feasibility of teaching materials; and (10) dissemination and implementation, reporting teaching material products in journals and implementing distance education systems. This type of research is a Quasi-Experimental Design. The replication of the research design used was one group pretest-posttest design, namely Opre-test X treatment Opost-test (Krippendorff, 2018).

Participants

This study involved 121 students taking atomic physics courses and spread across 12 regional offices in Indonesia, namely Jakarta, Serang, Bogor, Bandung, Semarang, Yogyakarta, Surabaya, Malang, Jember, Pangkal Pinang, Medan, and Pontianak. The sample is based on non-probability sampling using a purposive sampling technique. UT students have an admission process without minimum academic criteria and are not limited by age and profession. The chosen regional office criteria are based on students' smooth access to the internet, the number of students, the area's size, and the quality of management. Each regional office sample was 5-15 students with cumulative achievement index in the high, medium, and low category when taking physics courses in the previous year. Atomic physics teaching materials include the development of atomic theory, the spectrum of the hydrogen atom, quantum numbers. This research was conducted in the odd semester of the 2018/2019 academic year using a new generation of atomic physics teaching materials. The UT in all Indonesian regional offices can be seen in Figure 1.

Figure 1. Universitas Terbuka in Indonesia

Data Collection and Analysis

The learning process used learning tools in the form of a Indonesian National Qualifications Framework based curriculum, tutorial activity design, tutorial program units, learning resources, learning media, tutorial assignment design, student worksheets, and self-directed learning tests. Students got a pretest before learning and a posttest after the learning process. The instruments used to collect practical data include a checklist of aspects of learning implementation, a checklist of student activities' frequency every 5 minutes, and a lecture constraint sheet accompanied by alternative solutions. The instrument of effectiveness data includes: self-directed learning results tests and student response sheets consisting of statements and answer choices have been provided. Self-directed learning skill are based on indicators of initiation and persistence in learning, responsibility, discipline and great curiosity, confidence and a strong desire to learn, and able to organize time and set the pace of learning (Broad, 2006; Pandiangan et al., 2017). The research implementation was carried out an online tutorial based on blended learning between tutors and students for 8 meetings and structured assignments 3 times during the tutorial period, which was done in learning management system (LMS).

Table 1. Tutorial Implementation Procedure

1	2	3	4	5	6	7	8
Media: LMS Printed E-book **Tutorial Process:** Online	**Media:** LMS Printed E-book **Tutorial Process:** Online	**Media:** LMS Printed E-book Video Assignment: Structured 1 **Tutorial Process:** Online & Face to face	**Media:** LMS Printed E-book **Tutorial Process:** Online	**Media:** LMS Printed E-book Video Assignment: Structured 2 **Tutorial Process:** Online & Face to face	**Media:** LMS Printed E-book **Tutorial Process:** Online	**Media:** LMS Printed E-book Video Assignment: Structured 3 **Tutorial Process:** Online & Face to face	**Media:** LMS Printed E-book **Tutorial Process:** Online

Data analysis of the practicality of atomic physics teaching materials through the observation of 3 observers who assessed the number of aspects that were carried out so that the average category 3.6 ≤ very good <4.0, 2.6 ≤ good <3.5, 1.6 ≤ not good <2.5, 1.0 ≤ very bad <1.5 (Aryadoust & Raquel, 2019). Student activities during the lecture process are analyzed based on the frequency of activities that appear over a period of 5 minutes so that they can determine the average relevant student activity to reach a minimum percentage of 60% while using atomic physics teaching materials (Swarat et al., 2012). Constraints during the lecture process are analyzed based on alternative solutions that support students' self-directed learning skills. Analysis of the effectiveness data was further analyzed using inferential statistics with IBM SPSS 22 software. Analysis of the impact of students' self-directed learning skills from the pre-test, post-test, and N-gain scores using Paired Sample T-test if the data met normality or non-parametric using or Wilcoxon Signed Ranks-test. While the consistency of the impact of students' self-directed learning skills uses variance (ANOVA) if the data meets normality or is non-parametric using the Kruskall Wallis Test. The improvement of students' self-directed learning skills can be analyzed using the calculation of the average n-gain = (post-test score - pre-test score) / (maximum score - pre-test score), with categories including: (1) high if N-gain ≥ .70; (2) moderate if .70> N-gain ≥ .30; and (3) low if N-gain <.30 (Hake, 1999). Student responses to atomic physics teaching materials were analyzed using the Likert scale with the percentage category 19.99% ≤ strongly disagree <0%, 39.99% ≤ disagree <20%, 59.99% ≤ doubt <40%, 79, 99% ≤ agree <60%, 80% ≤ strongly agree <100% (Sax et al., 2008).

The UT applies dual pattern learning that is a face-to-face tutorial and online tutorial teaching. Blended learning is applied to online tutorial patterns in this research. The conceptualization of this research is supported by several components of the distance education system as follows.

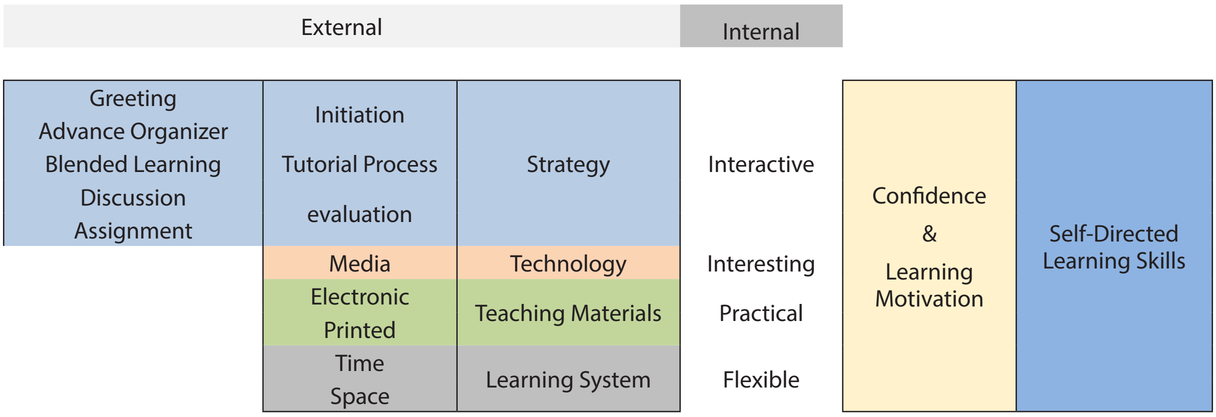

Figure 2. Conceptualization of the tutorial as a support for self-directed learning in a distance education

This study uses a open and distance education system that is supported by comprehensive components. The final goal in this tutorial process is student learning independence. Learning independence will be achieved if confidence and learning motivation are fulfilled. Internal and external factors play an important role in supporting self-directed learning. The learning environment can build internal factors for student learning that are interactive, interesting, practical, and flexible. External factors include strategies, technology, teaching materials, and learning systems. Blended learning in research is a supporting component of the tutorial process to build interactive learning strategies in the distance education system. Technology-based media in this research also supports interest in learning. This research also provides practical teaching materials in electronic form in the form of a virtual reading room (https://www.pustaka.ut.ac.id/lib/ruangbaca/) and print, distributed directly to students. The learning system in research is carried out flexibly. This learning system can optimize UT students who are scattered in various parts nationally and internationally. Also, the learning system used is not strictly timed. Students with various professions can listen to the initiation, tutorial process, and evaluation according to their available time to participate through the following LMS.

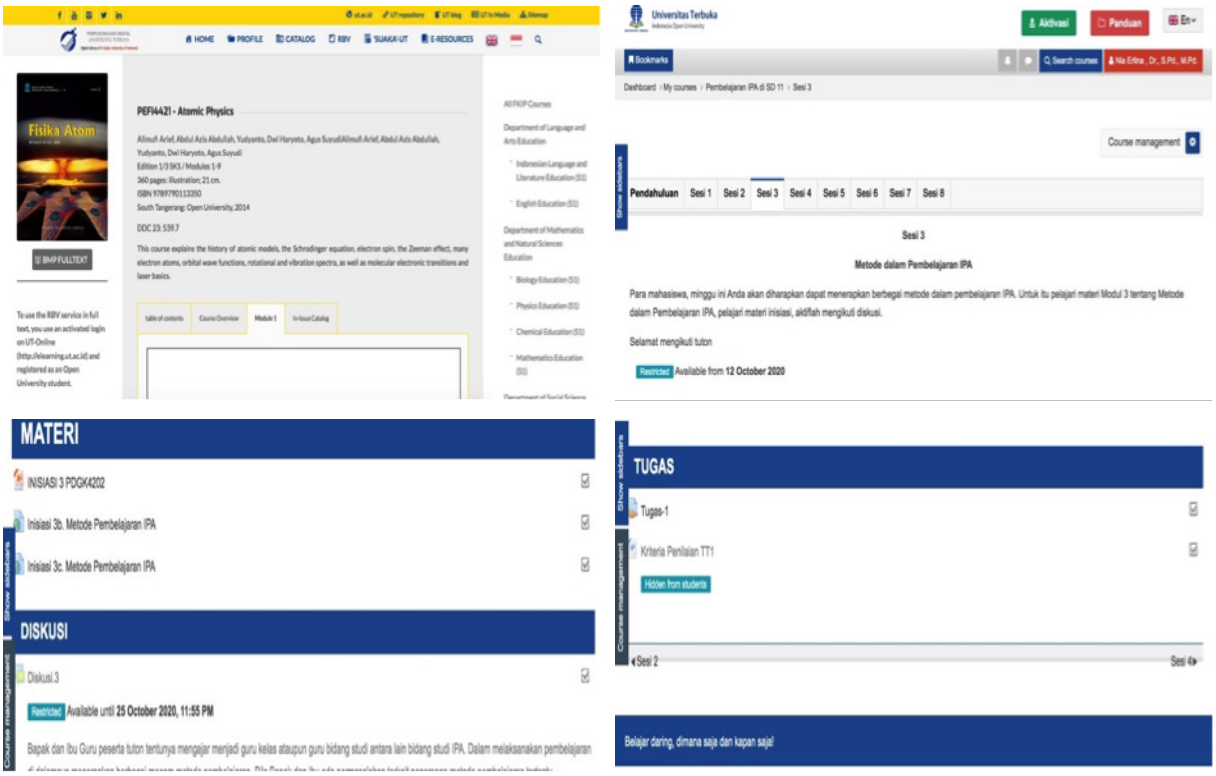

Figure 3. The LMS

Validity and Reliability

Learning tools were validated by learning experts and physics tutors before they were used for teaching. The validator determines the suitability of 26 statements against the learning device, including the content and construct's suitability. Validation test using Pearson product-moment correlation for validity and Cronbach-Alpha for Reliability. Table 3 provides information about the validity and reliability of learning devices. Table 3 shows the validation process with valid and reliable results. Pearson Correlation (r) on each validator indicates valid criteria. The validity test uses 26 statements of items with a significance of 5%. Cronbach's Alpha value .534> .39, then the decision making in the reliability test by four validators was concluded to be reliable. There is a significant correlation between variables. Each validator fulfills the aspects of content, language, presentation, and graphic feasibility assessment. The material expert stated that the material presented showed the concept of atomic physics according to competence using effective language and a clear sequence of presentation. Media experts state that teaching materials can support motivation, attractiveness, and interaction of stimulus and response based on display designs and illustrations. Besides, the tutor also stated that the blended learning used could support complete information in distance tutorials. The language presented is following the stage of student development with the aim of equitable education.

Table 2. Validity and Reliability Statistics

Validator	N of Items	Validity (Sig. (2-tailed))	Reliability Cronbach's Alpha
Content		.000 < .05	
Media	26	.000 < .05	.534 > .39
Tutor		.000 < .05	

FINDINGS

The results of this study present the supporting data on the practicality and effectiveness of atomic physics teaching materials in blended learning to improve self-directed learning skills in distance education systems as a whole as follows: (1) Implementation of tutorials; (2) student activities; (3) Constraints and solutions; (4) self-directed learning skills on each indicator; (5) Pretest and Posttest Self-directed learning skills; (6) N-gain of students' self-directed learning skills; (7) statistical analysis of the students' learning process; and (8) students' response to the application of atomic physics teaching materials in blended learning.

Implementing atomic physics teaching materials observed in the tutorial allows students to interact with tutors through additional explanations, information, discussions, and work on assignments. The average number of aspects performed per tutorial for all groups can be shown in Table 3.

Table 3. The feasibility of atomic physics teaching materials in face-to-face tutorials

No	Aspect	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Average
1	Inform the students of the tutorial objectives.	3.2	3.1	3.2	3.1	3.3	3.2	3.2	3.2	3.3	2.9	3.2	3.1	3.2
2	Explain teaching materials thoroughly and easily understood	3.7	3.8	3.7	3.6	3.5	3.8	3.5	3.5	3.6	3.6	3.7	3.6	3.6
3	Asking questions to students	3.4	3.2	3.5	3.3	3.2	3.3	3.5	3.5	3.4	3.4	3.5	3.3	3.4
4	Guide students in completing tutorial assignments	3.3	3.3	3.4	3.2	3.1	3.3	3.1	3.1	3.2	3.1	3.4	3.2	3.2
5	Summing up the material and feedback	3.1	3.3	3.3	3.2	3.1	3.0	3.2	3.2	3.1	3.2	3.3	3.2	3.2

*C : Testing Classes

The active role of students in the distance education system is a must. This shows that teaching designed by tutors must be oriented towards student activities. The average student activity during the tutorial process is observed for each group, and the meeting can be shown in Table 4.

Table 4. Average Percentage of Student Activities

No	Aspect	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Average
1	Listen to the tutor's explanation	82	83	82	83	82	83	81	81	82	80	81	81	81.8
2	Asking question	78	79	78	79	77	79	76	76	78	76	78	76	77.5
3	Respond to the tutor's questions	75	76	75	76	74	76	73	73	75	73	74	75	74.6
4	Discussion	87	88	87	88	86	88	85	85	87	85	85	86	86.5
5	Doing exercises or assignments	85	86	85	86	84	86	85	85	85	86	84	83	85.0

If the tutorial atomic physics teaching materials' problems can be solved collectively, the tutorial goes well. The situation experienced by students that hinders the smooth use of atomic physics teaching materials in the tutorial process as a whole can be shown in Table 5.

Table 5. Constraints in implementing atomic physics teaching materials

No.	Types of Constraints	Alternative Solutions
1	Presentation of atomic physics material in teaching materials is not comprehensive.	Describe the explanation of the material in atomic physics in a structured manner.
2	Teaching materials do not encourage student learning activities independently.	Addition of assignments that encourage students to learn independently.
3	Teaching materials in several sections have legibility that is difficult for students to understand.	The use of communicative sentences in writing atomic physics material.
4	Lack of illustration abstract examples in atomic physics teaching materials.	Added sample illustrations to provide a deeper understanding of the abstract matter of atomic physics.

The percentage of students' self-directed learning skills for each indicator of self-directed learning skills for the 12 test classes is shown in Figure 4.

Figure 4. Percentage of students' self-directed learning skills on each indicator

The average pre-test and post-test scores of students for each self-directed learning indicator for the 12 test classes are shown in Figure 5.

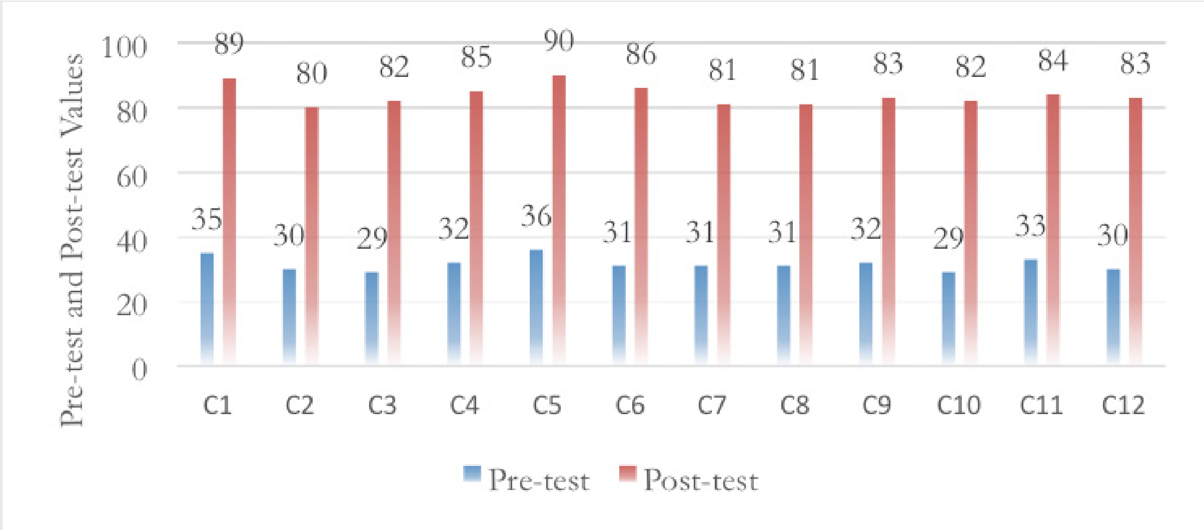

Figure 5. The average pre-test and post-test scores of students for each indicator of self-directed learning

Data from pre-test and post-test results are used in the N-gain analysis to improve self-directed learning after the tutorial using new generation atomic physics teaching materials. The average N-gain for the 12 test classes is shown in Figure 6.

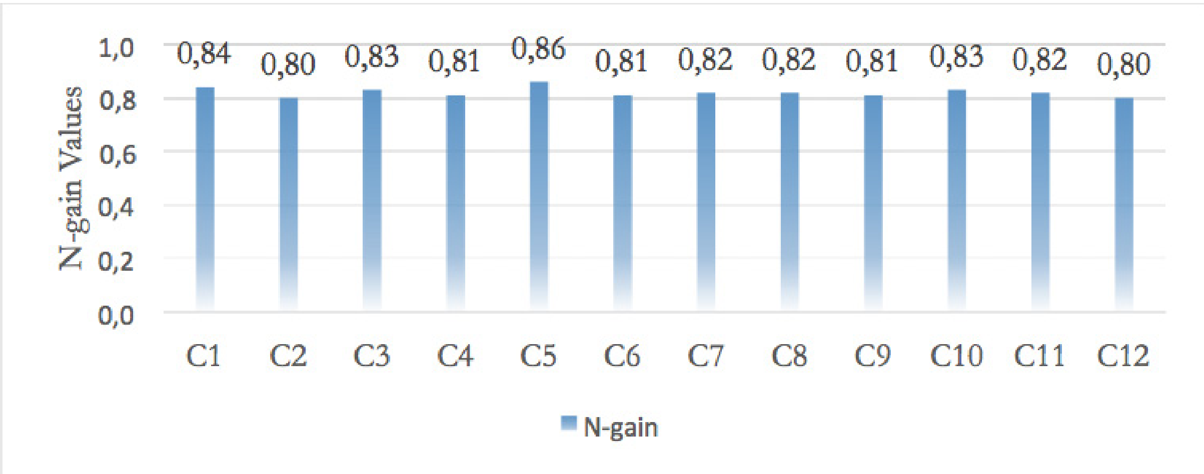

Figure 6. Average N-gain for the 12 test classes

Analysis of the impact of the application of atomic physics teaching materials based on the average pre-test and post-test values indicates that self-directed learning outcomes have increased. The results of the Paired Sample T-test statistical test based on normally distributed data can be shown in Table 6.

Table 6. The results of statistical testing paired sample t-test student self-directed learning

Kelas Uji	Paired Sample T-test (pre-test – post-test)	N	Mean	S	df	t	p
C1	Pair 1	9	57.42	8.50	8	36.96	p = < .0001
C2	Pair 2	6	57.91	8.72	5	33.17	p = < .0001
C3	Pair 3	15	57.85	8.04	14	35.23	p = < .0001
C4	Pair 4	12	57.76	8.31	11	37.40	p = < .0001
C5	Pair 5	8	57.43	8.27	7	37.99	p = < .0001
C6	Pair 6	9	57.06	9.02	8	28.96	p = < .0001
C7	Pair 7	13	57.64	8.82	12	33.30	p = < .0001
C8	Pair 8	9	57.64	8.82	8	33.30	p = < .0001
C9	Pair 9	10	56.27	9.10	9	32.12	p = < .0001
C10	Pair 10	11	57.85	8.04	10	35.23	p = < .0001
C11	Pair 11	12	58.22	7.84	11	37.82	p = < .0001
C12	Pair 12	7	57.13	8.37	6	31.28	p = < .0001

Consistency analysis of the impact of atomic physics teaching materials on the average N-gain value indicates that self-directed learning outcomes have increased consistently across all test classes. The ANOVA statistical test results based on data that are normally distributed can be shown in Table 7.

Table 7. The results of the ANOVA N-gain statistical test of the student's self-directed learning skills

N-gain	Sum of Squares	df	Mean Square	F	p
Between Groups	.186	11	.013	.832	.634
Within Groups	5.790	362	.016		
Total	5.977	376			

Student responses showed reactions or responses in the form of acceptance, rejection, or indifference. Student responses to students' relevance and reactions to attention, satisfaction, and self-confidence after using atomic physics teaching materials. The results of the Likert scale analysis with the average percentage can be shown in Table 8.

Table 8. The result of the percentage of student responses to atomic physics teaching materials

Criteria	Indicator	Response Rate (%)
Response	Relevance	92.3
Reaction	Attention	90.6
	Satisfaction	86.5
	Confidence	87.3

DISCUSSIONS AND CONCLUSION

Practicality

The use of appropriate teaching materials is needed in carrying out tutorial activities to improve student self-directed learning outcomes. Table 3 shows that the average tutorial feasibility using atomic physics teaching materials is the most dominant in explaining the teaching material thoroughly and **it is** easy to understand with an average value of 3.6. Teaching materials that have been developed make it easy for tutors to teach atomic physics material thoroughly. The teaching material symbols are given a description and a brief explanation to understand atomic physics material more easily. Besides, this teaching material can direct students to study independently because it contains problems and steps in solving these problems. Judging from self-directed learning characteristics, atomic physics teaching materials can direct students to think critically, creatively, and innovatively in solving a problem (Wechsler et al., 2018). Teaching materials that lead to self-directed learning are important to be applied to students who take distance education because students with tutors cannot face to face so that the media used by students must be able to meet student needs in achieving their competency goals (Zhang et al., 2008).

Indicators of the feasibility of atomic physics teaching materials in the tutorial are inseparable from the aspects contained therein, which include: informing the purpose of the tutorial to students, explaining the teaching material thoroughly and easily understood, asking questions to students, guiding students to complete the tutorial assignments, and concluding the material and feedback (Downes, 2007). Informing the purpose of tutorials to students is a tutoring program provided by the UT in face-to-face tutorial between tutors and students in the classroom to foster the student's self-directed learning process. This activity also aims to discuss materials that must be mastered by students if they are constrained in understanding them. The results showed that the tutor needed to inform the purpose of this tutorial to overcome the learning problems and difficulties they experienced and master the subjects' competencies (Forsyth, 2014).

Explaining the teaching material thoroughly and easy to understand, the tutorial material occupies a significant position in the atomic physics teaching material's overall structure. It must be prepared so that the feasibility of the tutorial can achieve the goal. These targets must be according to the basic competencies and instructional goals that students must achieve. Atomic physics teaching materials that have been developed contain tutorial material, basic competencies, tutorial objectives, and ways of evaluating, which are designed systematically so that students can achieve the tutorial objectives. The components in explaining the teaching material thoroughly explain the basic competencies, indicators, and tutorial objectives of atomic physics material. Tutors need to explain how to use this teaching material to be easy to use and understand. The results showed that the delivery of the material in teaching materials needed to be thoroughly explained by the tutor so that students could understand atomic physics material and the tutorial's objectives that had been determined could be achieved (Glynn & Duit, 2012). Also, by thoroughly explaining, students can apply the knowledge gained in class and apply it in everyday life (Abd-El-Khalick, 2013).

The process of asking students questions is an expression of an individual's curiosity about a certain thing, which could be the information obtained that will be useful for him. The questions asked by the tutor can be constructive, which means that by asking these questions, students can think critically and creatively to answer these questions (Bennett, 2003). The tutor also needs to pay attention to several components in asking a question, including (1) asking questions briefly and clearly; (2) focus the questions so that the answers given by students do not have broad meaning; (3) after asking the question, the tutor needs to give the students time to think; (4) asking questions in turn from one student to another; and (5) the tutor provides answer guidance if the answer is not correct. The results showed that when the tutor wanted to ask the students, the tutor wanted to know the extent of the student's understanding of atomic physics material after explaining using atomic physics teaching materials (Fortus & Vedder-Weiss, 2014).

When guiding students to complete tutorial assignments through a continuous and systematic process of assisting individuals who support knowledge development, the supervisor acts as a facilitator of student development; when viewed from a content perspective, guiding can be done by conveying or transferring teaching materials in the form of science, technology, and art using strategies and methods that suit the differences of each student (Hwang et al., 2009). Based on the strategies and methods used, guiding is more in giving motivation and coaching. The results showed that guidance activities could help students complete tutorial assignments to resolve student difficulties (Pandiangan et al., 2017). Besides, with tutor guidance activities, students can find out students' cognitive level so that tutors can use variations in guidance for old students to understand something with students who quickly understand something.

The process of concluding material and feedback by encouraging the emergence of final opinions based on previous descriptions. When concluding the material, it means taking the essence or essence of atomic physics material to make it easier for students to learn it. Besides, students also need feedback through providing information about whether or not student answers to the questions given are accompanied by additional information in the form of an explanation of the location of the error of the student's answer (Sadjati & Yuliana, 2017). Students' feedback during tutorial activities is, for example, asking questions so that feedback is obtained. Feedback is useful in encouraging student activity, assisting tutors in assessing and assisting in choosing evaluation forms. The results showed that through summarizing the material and feedback, a student could determine the extent of his understanding of atomic physics material (Verburg et al., 2019). Besides, this activity can be used to correct the learning development or learning progress of the students themselves. Feedback has three important components, including (1) recognition of the desired goal; (2) evidence about the present position; and (3) some understanding of a way to close the gap between the two (Nathenson & Henderson, 2018).

Based on Table 4, five student activities were observed when using atomic physics teaching materials, including listening to the tutor's explanation, asking questions, responding to the tutor's questions, conducting discussions, and doing exercises or assignments. The average percentage of student activity results get the highest score on the activity of conducting discussions by 86.5%, which is categorized as very active. Discussion activities lead students to exchange ideas with their group friends in solving a problem related to atomic physics. The results showed that through discussion activities, students could think actively and have the courage to express their opinions (Lin-Siegler et al., 2016). Also, discussion activities can foster a sense of responsibility and togetherness to find solutions to problems. Learning independence can be achieved if students are active in discussions. Judging from the characteristics of individuals who have the readiness to learn independently, students need to discuss with friends to foster curiosity about other opinions and foster a sense of responsibility to complete the assigned task (Broad, 2006). The discussion process can pave the way for students who have difficulty achieving the tutorial objectives. The activity of listening to the tutor's explanation is through listening and paying attention to the words spoken by others. Students need to listen to what is conveyed by the tutor so that the information obtained can be understood properly. The results showed that listening to tutors' explanations can be used as a means for the communication process to run well (Howard et al., 2016). Students, as good listeners after the listening process, can respond and conclude the results of the information that has been listened.

The activity of asking questions through an expression of student curiosity about a certain thing can be useful information. The activity of asking questions shows a dynamic interaction between tutors and students and between students and students. Asking activities will be more effective if the questions asked are sufficiently weighty, easy to understand, or relevant to the topic being discussed. The results showed that when students ask the tutor, it means that they have shown a high sense of curiosity and can train students to foster critical thinking skills (Laurillard, 2013). The tutor can assess the level of student understanding of the questions asked to take appropriate next steps applied in the tutorial. Activities to respond to the tutor's questions when students can respond to questions from the tutor properly, it can be assumed that the student has understood the material presented. The response to the question depends on the question's characteristics, which requires students to think critically and creatively, not just remembering or mentioning (Wen et al., 2015). The tutor provides questions that lead to open-ended questions, allows students to answer diverse questions, assesses students holistically, enables students to interpret atomic physics material from the answering process. The results showed that the ability to respond quickly to questions from the tutor arose from listening to material well-being so that students did not find it difficult to answer questions from the tutor.

Activities carry out discussions through scientific meetings so that students can exchange ideas in solving a problem. Discussions involve two or more students who interact verbally and face each other regarding the objectives or objectives of atomic physics material by exchanging information and maintaining or solving problems. When discussing, students can freely express their perceptions and opinions. The main purpose of the discussion activity is to find the best solution to a problem in applying atomic physics (Carpenter, 2006). With the discussion, students can exchange ideas with other students in solving atomic physics material problems. The results showed that discussion activities could foster critical thinking skills and train students' courage to express their public opinions (Wehmeyer et al., 2012). The activity of doing exercises or tasks must be done and becomes the responsibility of a person. Tutors give assignments to students to find out to what extent students understand the material being taught. The assignment aims to make students understand the new generation of atomic physics textbooks. Students carry out exercises while doing assignments so that students' experience in learning something becomes more integrated. The results showed that by giving assignments, the tutor could find out the strengths and weaknesses of each student's mastery of concepts so that the tutor could take further actions that were suitable for learning (Perraton, 2012)

The use of atomic physics teaching materials is inseparable from the constraints or problems that arise during the tutorial process, as shown in Table 5. Constraints that appear in the presentation of atomic physics teaching materials in teaching materials are not comprehensive. The tutor describes an explanation of atomic physics in a structured manner. Atomic physics material is classified as abstract so that by describing the explanation of atomic physics in a structured manner, students can more easily understand the material (Giancoli, 2016). UT students must study independently so that teaching materials are needed, containing activities that lead students to study independently. Teaching materials like this can meet students' needs to think critically, creatively, and innovatively in solving a problem. Presentation of activities made contextually makes it easier for students to understand it because students can see firsthand the problems they face. Besides, it is necessary to add illustration examples to understand better students' abstract material (Butcher, 2015). The characteristics of atomic physics material are classified as abstract material and cannot be directly observed by students. Most students receive atomic theory learning like studying history or something that already exists, and they must accept it as it is (Feynman, 2018). Therefore, atomic physics teaching materials need to accommodate atomic physics material characteristics and make learning student-centered. Good teaching materials must contain content that can make students learn independently. This is so that students can explore their own thoughts to find answers to the problems given. Atomic physics teaching materials need to be added and illustration examples classified as abstract because the level of student thinking has entered the formal operational level, which requires students to think abstractly. Instructional objectives require students to understand abstract illustrations from atomic physics.

Effectiveness

Teaching materials can be said to be effective if they can increase students' self-directed learning skills. Based on Figure 4, there is an increase in the average value of the pre-test and post-test scores of the self-directed learning indicators when using new generation atomic physics teaching materials. This is indicated by the average pre-test score of 32, which then increases the average post-test score of 84.9. Learning independence demands a great deal of responsibility on students, so they try to carry out various activities to achieve learning goals (Glynn & Duit, 2012). In organizing and disciplining himself in developing learning abilities of his own accord. In addition to responsibility, students' high motivation is essential for self-directed learning (Howard et al., 2016). Students who use a thinking composition strategy or self-directed learning style produce a complete learning process and learning outcomes and qualitatively have better stories of experiences during the learning process written in themselves than students who do not receive self-regulation instruction (Blair & Raver, 2015). Figure 4 shows the increase in self-directed learning outcomes after using atomic physics teaching materials, as shown by the average N-gain value of .82 ($\alpha \geq .8$), categorized as high. These results indicate that atomic physics teaching materials can improve student learning independence. This increase is because in atomic physics teaching materials, there is a comprehensive explanation of the material to understand the material more easily. Besides, there are also abstract illustrations that can help students to achieve the goals of the tutorial. Students can learn independently if the content in the media used can make students think creatively and develop skills independently (Wiley et al., 2014). The tutorial that is applied also plays an important role in fostering self-directed learning for distance students. The tutorial activities carried out can trigger student self-directed learning activities so that students can observe, think, behave, and act in dealing with any problems that are the result of the learning process.

Based on Table 6, statistical analysis through paired sample t-test has results that H_0 is rejected, and H_1 is accepted, which means a significant difference between the pre-test and post-test scores of each test class. This proves that atomic physics teaching materials are proven to be effective in increasing students' self-directed learning skills. The results of the development of atomic physics teaching materials are carried out systematically starting from the design and development process, which can be in the form of developing their own activities to testing teaching materials (Plomp, 2013). Knowledge of the factors that affect the quality of results needs to be considered in teaching materials. Teaching materials explain the material thoroughly, and in it, there are abstract problems related to atomic physics. This teaching material makes students interested in learning it is because of the innovations developed based on the needs analysis of the teaching materials commonly used. Table 7 shows the results of statistical tests through ANOVA obtained a significance value of .634> .05 so that H_0 is accepted and H_1 is rejected. Thus it can be concluded that there is no significant difference from all test classes so that atomic physics teaching materials are effective for application to students who have low, medium, and high abilities. This atomic physics teaching material is suitable for UT students because the teaching material has explained the material thoroughly and is equipped with illustration examples making it easier for students to understand atomic physics material, which is classified as abstract. For example, topics on electron configuration and quantum numbers, blended learning can support direct student interaction with tutors. Tutors can directly detect writing electron configurations that are often reversed, understanding quantum numbers (main quantum numbers, spin, azimuth, magnetic), which are still often wrong. The determination groups and periods are often wrong because students misunderstand the outer electrons. This interaction process can overcome the weaknesses of teaching materials when students learn independently. The variations and innovations that are raised compared to the teaching materials commonly used by UT students are also a separate supporting factor to help UT students improve their self-directed learning skills. The components in atomic physics teaching materials include learning instructions for students, competencies to be achieved, supporting information, practice questions, student worksheets, and evaluation (Pucciarelli & Kaplan, 2016).

Table 8 shows that the average result of student responses regarding the relevance of atomic physics teaching materials with atomic physics lecture material is 92.3, with a very high category. The average results of student reactions related to attention, satisfaction, and self-confidence were 90.6, 86.5, and 87.3, respectively, with very high categories. This result is relevant to Figure 3, showing that students positively responded from all indicators to the new generation of atomic physics teaching materials. confidence and a strong desire to learn shows the largest percentage. The teaching materials used can make it easier for students to understand atomic physics material, help students have discussions with a group of friends if students find it difficult, and foster student learning independence. For example, the atomic theory of Dalton, Thompson, Rutherford, Bohr, and quantum mechanics. This topic is presented audiovisually with an attractive color appearance. Each theory's strengths and weaknesses are presented based on animated experiments to support the wealth of e-books and printed books. Besides, students' interest in learning using atomic physics teaching materials can make it easier for tutors to deliver learning material (Kent et al., 2016). According to the Indonesian dictionary, it means the tendency of the heart to like something in terms of the meaning of interest. If students already like learning, their hearts and minds will be fully poured into the learning (Herman, 2017).

Based on Table 8, the analysis of student responses to atomic physics teaching materials shows responses in the form of relevance and reactions in attention, satisfaction, and self-confidence. Relevance is the relationship between two things that are interrelated when they are matched with one another. The results showed that atomic physics teaching materials were relevant to physics lecture material given by the tutor. The benefit of the relevance of the teaching material and the lecture material used is that it can meet the needs of students to understand atomic physics material. Besides, the illustration examples contained in the teaching materials can be used as a means to apply atomic physics in everyday life. Hydrogen is the element with the greatest abundance in the universe. For example, students can determine the hydrogen emission line spectrum wavelength in the visible area in the tutorial process. Teaching materials can explain Balmer's formula, $1/\lambda = R((1/22)-(1/n2))$; $n=3,4,5$ …, based on the hydrogen atom's energy level through interactive videos. Attention is one of the psychological aspects a person has when he sees an object that he thinks is interesting (Erlina et al. 2018). Students will focus their attention if the tutorial used by the tutor is interesting or the media used makes it easier for students to understand the material. The results show that atomic physics teaching materials can focus students' attention on studying the material thoroughly. This is because in teaching materials, the material is explained thoroughly and the sentences used are easy to understand by students so that students feel that the teaching material can help them achieve their learning goals (Wechsler et al., 2018).

Besides, satisfaction is a feeling of pleasure or disappointment that a person has that appears after comparing the product's performance against the expected results. Students will feel satisfied if the tools or media they use in the tutorial can help them achieve competency goals. Student satisfaction because atomic physics teaching materials have illustrative examples that can help understand abstract material and assignments or exercises that can encourage student self-directed learning activities. Combining illustration examples with the addition of assignments at the end of the tutorial makes students feel satisfied to use this teaching material in the tutorial. Using teaching materials that have been designed according to learning needs, students are directed to become active learners because they can read or study the material in teaching materials before participating in learning activities. Self-confidence is a positive attitude that an individual has to develop self-awareness, have independence, and have the ability to have everything he wants. Someone who already has a high sense of self-confidence can do something according to his mind. The results showed that the teaching materials are part of the tools that must be prepared by the tutor to teach the material to support the tutorial process (John, 2006). Natural physics teaching materials make students more confident in understanding atomic physics material and apply it in everyday life. This is because atomic physics teaching materials have been designed to meet the needs of UT students to improve their self-directed learning skills. Besides, this teaching material has also fulfilled one of the characteristics of the teaching material, namely adaptive, where the content in the teaching material is adjusted to the development of science and technology so that students who use the teaching material have high self-confidence to achieve their learning goals (Kent et al., 2016).

Based on the research results and discussion above, the study concludes about the practicality and effectiveness of atomic physics teaching materials to improve students' self-directed learning skills in the distance education system. The results of the practicality analysis, including student activity and feasibility, showed very good results. Constraints that arise in the presentation of the material are not comprehensive enough that the tutor explains the atomic physics in a structured manner. The analysis of the effectiveness, including the improvement of self-directed learning outcomes, showed that the average N-gain value was categorized as high. Besides, impact testing using the paired sample t-test 2-tailed showed a significant difference between each test class's pre-test and post-test scores. The consistency of the impact using the 2-tailed ANOVA showed no significant difference between all test classes. Student responses to atomic physics teaching materials showed the average results of responses and reactions were very agreeable.

LIMITATIONS AND RECOMMENDATIONS

This study has several limitations in implementing tutorials through blended learning before the covid 19 pandemics. Open and distance education students have distance learning activities based on heterogeneous characteristics of age, occupation, status, and place of residence without restrictions. Asynchronous activities provide opportunities for students to independently learn through the learning management system, printed, and e-book media. Some students still have difficulty understanding the objectives and concluding the tutorial material because asynchronous has a passive learning condition in social interaction. The face-to-face activity provides the advantage of actively supporting students' independent learning. These obstacles become recommendations on optimizing face-to-face activities to apply atomic physics teaching materials observed in the tutorials allowing students to interact with tutors through additional explanations, information, discussions, and doing assignments. Face-to-face activities in this study also support the weakness of student responses to the tutor's questions, initiation, and persistence. Nevertheless, technological assistance in online tutorials and face-to-face tutorials makes it easier for students to form their different abilities and understand students' characteristics and needs in online learning. This study provides recommendations for improving blended learning activities during the pandemic, namely applying andragogy models (conditions, interests, and past experiences) and online learning paths (learning, exploring, applying, connecting, evaluating).

Acknowledgements: We want to express our gratitude to the Institute for Research and Community Service at the Universitas Terbuka through the University's Prime Research scheme with contract Number 6434 / UN31.2 / DN / 2018 for financial assistance in completing this research.

BIODATA and CONTACT ADDRESSES of AUTHORS

Nia ERLINA is Doctoral at the Department of Physics and Science Education, Universitas Pendidikan Ganesha, Indonesia. She completed her Doctoral degree in Science Education from Universitas Negeri Surabaya (2018). She as a lecturer at Universitas Pendidikan Ganesha. She is also active in conducting research, writing learning books, publishing and as a reviewer several international journals. Her research interests include the design and development of learning model and thinking skill.

Nia ERLINA
Universitas Pendidikan Ganesha
Address: Jl. Udayana No. 11, Singaraja, Bali, Indonesia
Phone: (+62)82264496864
E-mail: nia.erlina1@gmail.com ; niaerlina@undiksha.ac.id

PRAYEKTI is Doctoral at the Department of Physics Education, Universitas Terbuka, Indonesia. She completed her Doctoral degree in Learning Technology from Universitas Negeri Malang (2015). She as a lecturer in Physics Education, Universitas Terbuka. She is also active in conducting research, writing learning books and publishing several international journals. Her research interests include the design and development of technology and physics learning instruction in distance learning system.

PRAYEKTI
Universitas Terbuka
Address: Jl. Cabe Raya, Jakarta, Indonesia
Phone: (+62)81318590993
E-mail: prayekti@ecampus.ut.ac.id

Iwan WICAKSONO is Doctoral at the Department of Science Education, Universitas Jember, Indonesia. He completed his Doctoral degree in Science Education from Universitas Negeri Surabaya (2017). He as a lecturer in Science Education Universitas Jember. He is also active in conducting research, writing learning books, publishing and as a reviewer several international journals. His research interests include the design and development of learning model and virtual learning media.

Iwan WICAKSONO
Universitas Jember
Address: Jl. Kalimantan No. 37, East Java, Indonesia
Phone: (+62)82336199019
E-mail: iwanwicaksono.fkip@unej.ac.id

REFERENCES

Abd-El-Khalick, F. (2013). Teaching with and about nature of science, and science teacher knowledge domains. *Science & Education*, *22*(9), 2087-2107. https://doi.org/10.1007/s11191-012-9520-2

Agaoglu, O, Demir, M. (2020). The integration of 21st century skills into education: an evaluation based on an activity example. *Journal of Gifted Education and Creativity*, *7*(3), 105-114. https://dergipark.org.tr/en/pub/jgedc/issue/56934/811066

Aryadoust, V., & Raquel, M. (2019). *Quantitative data analysis for language assessment volume I: Fundamental techniques*. New York: Routledge.

Atenas, J., & Havemann, L. (2013). Quality assurance in the open: An evaluation of OER repositories. INNOQUAL: *The International Journal for Innovation and Quality in Learning*, *1*(2), 22-34. https://eprints.bbk.ac.uk/id/eprint/8609

Bennett, J. (2003). *Teaching and learning science: A guide to recent research and its applications*. London: Continuum.

Berg, G. (2020). Context matters: Student experiences of interaction in open distance learning. *Turkish Online Journal of Distance Education*, *21*(4), 223-236. https://doi.org/10.17718/tojde.803411

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology*, *66*(1), 711-731. https://doi.org/10.1146/annurev-psych-010814-015221

Broad, J. (2006). Interpretations of self-directed learning in further education. *Journal of Further and Higher Education*, *30*(2), 119-143. https://doi.org/10.1080/03098770600617521

Budiastra, A. A. K., Erlina, N., & Wicaksono, I. (2019). Video-based interaction through teacher working group forum to increase elementary school teachers' professionalism. *The New Educational Review*, *57*(3), 187-199. doi: 10.15804/tner.2019.57.3.15

Budiastra, A. A. K., Wicaksono, I., Erlina, N. (2020). The effectiveness of video-based interaction on professional science teachers to improve elementary school students achievements. *Journal for the Education of Gifted Young Scientists*, *8*(3), 1291-1304. https://doi.org/10.17478/jegys.715139

Budiastra, A. A., Wicaksono, I., & Sanjaya, I. (2020). The new generation self-directed teaching materials of natural science in elementary schools validity tests. *International Journal of Instruction*, 13(4), 763-780. https://doi.org/10.29333/iji.2020.13447a

Butcher, N. (2015). *A basic guide to Open Educational Resources (OER): Commonwealth of Learning (COL).* Vancouver: Canada.

Carpenter, J. M. (2006). Effective teaching methods for large classes. *Journal of Family & Consumer Sciences Education*, *24*(2), 13-23. https://www.natefacs.org/Pages/v24no2/v24no2Carpenter.pdf

Clark, C. E. J., & Post, G. (2021). Preparation and synchronous participation improve student performance in a blended learning experience. *Australasian Journal of Educational Technology*, 187-199. https://doi.org/10.14742/ajet.6811

Downes, S. (2007). Models for sustainable open educational resources. *Interdisciplinary Journal of E-Learning and Learning Objects*, *3*(1), 29-44. https://www.learntechlib.org/p/44796/

Endres, M., Bernien, H., Keesling, A. (2016). Atom-by-atom assembly of defect-free one-dimensional cold atom arrays. *Science*, *354*(6315), 1024-1027. doi: 10.1126/science.aah3752

Erlina, N., Susantini, E., & Wasis, W. (2018). Common false of student's scientific reasoning in physics problems. *Paper presented at the Journal of Physics: Conference Series* 1108 012016. doi :10.1088/1742-6596/1108/1/012016

Erlina, N., Susantini, E., Wasis, Wicaksono, I., & Pandiangan, P. (2018). The effectiveness of evidence-based reasoning in inquiry-based physics teaching to increase students' scientific reasoning. *Journal of Baltic Science Education*, *17*(6), 972-985. doi: 10.33225/jbse/18.17.972

Evans, J. C., Yip, H., Chan, K., Armatas, C., & Tse, A. (2020). Blended learning in higher education: professional development in a Hong Kong university. *Higher Education Research & Development*, *39*(4), 643-656. https://doi.org/10.1080/07294360.2019.1685943

Feynman, R. P. (2018). *There's plenty of room at the bottom: An invitation to enter a new field of physics. In Handbook of Nanoscience, Engineering, and Technology* (pp. 26-35). Florida: CRC Press.

Forsyth, I. (2014). *Teaching and learning materials and the internet*. New York: Routledge.

Fortus, D., & Vedder-Weiss, D. (2014). Measuring students' continuing motivation for science learning. *Journal of Research in Science Teaching*, *51*(4), 497-522. https://doi.org/10.1002/tea.21136

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational research an introduction, seventh editions*. United State of America: University of Oregon.

Giancoli, D. C. (2016). *Physics: Principles with applications*. Boston: Pearson.

Glynn, S. M., & Duit, R. (2012). *Learning science meaningfully: Constructing conceptual models. In Learning science in the schools* (pp. 15-46). New York: Routledge.

Hake, R. R. (1999). *Analyzing change/gain scores*. CA USA: Indiana University Press.

Herman, H. (2017). Loyalty, trust, satisfaction and participation in universitas terbuka ambiance: students' perception. *Turkish Online Journal of Distance Education*, *18*(3), 84-95. https://doi.org/10.17718/tojde.328937

Howard, J., Gagne, M., Morin, A. J. S., & Van den Broeck, A. (2016). Motivation profiles at work: A self-determination theory approach. *Journal of Vocational Behavior*, *95*(1), 74-89. https://doi.org/10.1016/j.jvb.2016.07.004

Hwang, G.-J., Yang, T.-C., Tsai, C.-C., & Yang, S. J. H. (2009). A context-aware ubiquitous learning environment for conducting complex science experiments. *Computers & Education*, *53*(2), 402-413. https://doi.org/10.1016/j.compedu.2009.02.016

John, P. D. (2006). Lesson planning and the student teacher: Re-thinking the dominant model. *Journal of Curriculum Studies*, *38*(4), 483-498. https://doi.org/10.1080/00220270500363620

Kaye, A. T., & Rumble, G. (2018). *Distance teaching for higher and adult education*. New York: Routledge.

Kent, C., Laslo, E., & Rafaeli, S. (2016). Interactivity in online discussions and learning outcomes. *Computers & Education*, *97*(1), 116-128. https://doi.org/10.1016/j.compedu.2016.03.002

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*. California: Sage Publications.

Laurillard, D. (2013). *Teaching as a design science: Building pedagogical patterns for learning and technology*. New York: Routledge.

Li, X., Yang, Y., Chu, S. K. W., Zainuddin, Z., & Zhang, Y. (2020). Applying blended synchronous teaching and learning for flexible learning in higher education: an action research study at a university in Hong Kong. *Asia Pacific Journal of Education*, 1-17. https://doi.org/10.1080/02188791.2020.1766417

Lin-Siegler, X., Dweck, C. S., & Cohen, G. L. (2016). Instructional interventions that motivate classroom learning. *Journal of Educational Psychology*, *108*(3), 295-299. http://dx.doi.org/10.1037/edu0000124

Maftei, G., & Popescu, F. F. (2012). Teaching atomic physics in secondary school with the jigsaw technique. *Romanian Reports in Physics*, *64*(4), 1109-1118. http://www.rrp.infim.ro/2012_64_4/art20Maftei.pdf

Nathenson, M. B., & Henderson, E. S. (2018). *Using student feedback to improve learning materials*. New York: Routledge.

Pandiangan, P., Sanjaya, M., Gusti, I., & Jatmiko, B. (2017). The validity and effectiveness of physics self-directed learning model to improve physics problem solving and self-directed learning skills of students in open and distance education systems. *Journal of Baltic Science Education*, *16*(5). 651-665. http://oaji.net/articles/2017/987-1509213674.pdf

Perraton, H. (2012). *Open and distance learning in the developing world*. New York: Routledge.

Plomp, T. (2013). *Educational design research: An introduction educational design research*. Netherlands: Institute for Curriculum Development (SLO).

Pucciarelli, F., & Kaplan, A. (2016). *Competition and strategy in higher education: Managing complexity and uncertainty.* Business Horizons, *59*(3), 311-320. https://doi.org/10.1016/j.bushor.2016.01.003

Richter, T., & McPherson, M. (2012). *Open educational resources: education for the world.* Distance Education, *33*(2), 201-219. https://doi.org/10.1080/01587919.2012.692068

Sadjati, I. M., Yuliana, E., & Suparti. (2017). Peningkatan kualitas buku materi pokok berdasarkan hasil uji coba lapangan [Quality improvement of basic material books based on field test results]. *Jurnal Pendidikan Terbuka dan Jarak Jauh*, *15*(2), 99-111. https://doi.org/10.33830/ptjj.v15i2.593.2014

Sax, L. J., Gilmartin, S. K., Lee, J. J., & Hagedorn, L. S. (2008). Using web surveys to reach community college students: An analysis of response rates and response bias. *Community College Journal of Research and Practice*, *32*(9), 712-729. https://doi.org/10.1080/10668920802000423

Swarat, S., Ortony, A., & Revelle, W. (2012). Activity matters: Understanding student interest in school science. *Journal of Research in Science Teaching*, *49*(4), 515-537. https://doi.org/10.1002/tea.21010

Verburg, M., Snellings, P., Zeguers, M. H. T., & Huizenga, H. M. (2019). Positive-blank versus negative-blank feedback learning in children and adults. *Quarterly Journal of Experimental Psychology*, *72*(4), 753-763. https://doi.org/10.1177/1747021818769038

Wechsler, S. M., Saiz, C., Rivas, S. F., Vendramini. (2018). Creative and critical thinking: Independent or overlapping components. *Thinking Skills and Creativity*, *27*(1), 114-122. https://doi.org/10.1016/j.tsc.2017.12.003

Wehmeyer, M. L., Shogren, K. A., Palmer, S. B., & Boulton, A. (2012). The impact of the self-determined learning model of instruction on student self-determination. *Exceptional Children*, *78*(2), 135-153. https://doi.org/10.1177/001440291207800201

Wen, Z., O'Neill, D., & Maei, H. (2015). Optimal demand response using device-based reinforcement learning. *IEEE Transactions on Smart Grid*, *6*(5), 2312-2324.doi: 10.1109/TSG.2015.2396993

Wicaksono, I., Madlazim, & Wasis. (2017). The effectiveness of virtual science teaching model (VS-TM) to improve student's scientific creativity and concept mastery on senior high school physics subject. *Journal of Baltic Science Education*, *16*(4), 549-561. http://oaji.net/articles/2017/987-1503905158.pdf

Wiley, D., Bliss, T. J., & McEwen, M. (2014). *Open educational resources: A review of the literature. In Handbook of research on educational communications and technology* (pp. 781-789). Germany: Springer.

Zazkis, R., Liljedahl, P., & Sinclair, N. (2009). Lesson plays: Planning teaching versus teaching planning. *For the learning of mathematics*, *29*(1), 40-47. https://www.jstor.org/stable/40248639

Zhang, L., Han, Z., & Gao, Q. (2008). Empirical study on the student satisfaction index in higher education. *International Journal of Business and Management*, *3*(9), 46-51.doi: 10.5539/IJBM.V3N9P46