Technology-enabled active learning simulations (TEALSim) on distance learning of physics

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	Abstract
	The effect of the spread of the Coronavirus 2019 has an impact on the implementation of face-to-face learning to distance learning. So that the learning that applies in Indonesia today needs to be supported by the right technology and supporting teaching materials. The selection of appropriate and interesting media will have a good impact on the quality of distance learning. This study aims to determine students' perceptions of the use of Technology-Enabled Active Learning Simulation (TEALSim) which is rich in interactive simulations and videos in physics learning and to determine the correlation between student perceptions of learning outcomes. With 26 students as respondents who were selected by random sampling. After using TEALSim, students fill out a questionnaire via google form that has been developed and validated by experts and then students take a concept understanding test. Based on the analysis, it shows that the majority of students have a perception with a percentage above 80% which is in the good category and in general is in the very good category. Besides, there is a good correlation between student perceptions and learning outcome data which is indicated by a correlation value of 0.7.

To cite this article:
Swandi, A., Rahmadhanningsih, S., Viridi, S. (2023). Technology-enabled active learning simulations (TEALSim) on distance learning of physics. *Thabiea : Journal of Natural Science Teaching*, 6(1), 65-75.

Introduction

Many universities have used Blended Learning to support distance learning (Santi Maudiarti, 2018). Especially in a pandemic situation that forces universities to change the learning format from face-to-face learning to distance learning. Of course, there are deficiencies in the implementation of distance learning, especially the quality of the output produced and the effectiveness of the learning (I. F. Ahmad, 2020). Students' understanding of concepts will be different if learning is done face-to-face and online learning.

Various kinds of adjustments by lecturers and universities have been made, such as the use of learning technology-based applications. Several distance learning applications have been widely used, such as the use of the zoom application, google meet, moodle, and others (Dushkevych, Barabashchuk, & Hutsuliak, 2020; Napitupulu, 2020). However, most of the use of these applications only makes learning in one direction, in other words, lecturers dominate learning. Student activities are reduced, besides that lecturers also find it difficult to control student activities during learning.

Higher education has faced the challenge of applying traditional practices and modifying them to be more student-centered (Hartikainen, Rintala, Pylväs, & Nokelainen, 2019). Learning that is more student-centered and activates instructional procedures has had greater achievement in student learning and the development of general work-life skills or competencies. Active learning in higher education is one solution in improving the quality of learning outcomes (Palloan & Swandi, 2019). So, lecturers need to determine the right media and can be used by students to support this. Distance learning for a variety of subjects certainly has different methods and approaches, especially in the science and social fields. As part of science, learning physics has been done a lot both through observation of natural phenomena around us and by direct learning in the classroom. The use of experimental methods has been proven to be able to improve students' understanding of physics concepts such as the results of research by Subekti and Ariswan which stated that the use of experimental methods in learning physics was able to improve cognitive learning outcomes and science process skills (Subekti & Ariswan, 2016). There is also research by Handika which states that learning physics through guided inquiry with experimental and demonstration methods is viewed as increasing student activity and attention. The use of the experimental method with the guided inquiry model can also increase student creativity in science learning (Sen & Oskay, 2016).

However, the use of experimental methods in learning physics with a distance learning format is difficult. This is because the location of the laboratory is quite far from where the students live, besides that the availability of practicum tools for the number of students is still lacking (S. Ahmad & Bunga, 2015; Amin, Haris, & Swandi, 2019). It is very difficult for students to borrow equipment in the laboratory because of the limited number of equipment and the risk of damage is quite large, especially laboratory equipment for abstract physics concepts such as black body radiation, photoelectric effect, and Compton effect (Amin et al., 2019; Ahmad Swandi, Nurul, & Irsan, 2015). Various applications have been made to change the format of experimental learning in the laboratory into virtual experiments. One of them is that the PhET Simulation introduces interactions to each simulation. User interaction with the application is driven by a user interface and intuitive controls, using buttons, click-and-drags, sliders, and immediate responses are provided for each user interaction (Mastorodimos, Chatzichristofis, Jimoyiannis, & Christodoulou, 2018). However, the use of PhET and other applications is more widely used in face-to-face learning, where lecturers can more easily control application usage. The use of interactive simulations and integrated with online learning platforms is something that must be developed.

Therefore, the importance of technological media in learning physics is developed and used to support observation activities even in the distance learning process. This technology is also expected to increase student activity, collaboration, and problem-solving skills. One of the learning technologies that can be used is the Technology-Enabled Active Learning Simulation (TEALSim). According to Hasan et al, TEAL emphasizes the use of active learning and small groupings during the learning process. Interaction and discussion are carried out through the Interactive Response System (IRS) which allows instructors or lecturers to ask questions, track and assess student responses to questions (Hassan, Puteh, & Muhamad Sanusi, 2018). The use of the IRS makes it easy for lecturers and students to evaluate the feasibility of initial learning to final evaluation. The main objective of TEAL is

to create a learning format that involves students in studying physics and matters related to technology more deeply so that they can gain a more comprehensive understanding of the content being studied both conceptually and analytically (Shieh, 2010, 2012).

TEALSim was developed to present a learning environment that seems real through technology, there are several advantages of this application, namely (1) making abstract physics concepts easy to apply, (2) making invisible phenomena visible, (3) increasing understanding concept, (4) student rules for manipulating existing physics parameters and the effects can be seen directly, (5) presenting a technology-based learning environment that is easy to use even though the user is not a technology expert or programming language. The use of TEALSim is rich in instructional videos and instructional videos as well as interactive simulations integrating remote lectures, problem-solving, and direct observation (A. Swandi, Amin, Viridi, & Eljabbar, 2020). So it is hoped that students will be more active in participating in physics learning. In this research, experiment-based learning technology is supported by learning instruments that can to direct students to learn actively and independently. The teaching materials are also integrated with the online learning platform, namely Edmodo and the zoom application. So that it allows students to study anywhere and anytime. The use of TEALSim in distance learning adopts an Interactive Method Based on Increased Focus on Problem Tasks and Experiments (Interactive P&E Method) (Krišťák, Němec, & Danihelová, 2014). In this research, several terms are used as synonyms for TEALSim such as interactive simulation and Virtual and Remote Lab (VRL). Therefore the research problems in this study are (1) how are students' perceptions of the use of Technology-Enabled Active Learning Simulation (TEALSim) in physics learning? What is the correlation between students' perceptions of learning outcomes after using the Technology-Enabled Active Learning Simulation (TEALSim)?

Method

This research includes quantitative research with a survey and test approach using a questionnaire and test sheets as instruments. Research like this is used to collect information in the form of personal opinions from various respondents on a particular topic (Perdana et al., 2020). The choice of this type of research is based on the implementation of distance learning so that it is not possible to conduct direct surveys and tests. The instrument used was developed from google form and adapted from various sources then validated by 3 experts before use. The validators are science learning technology experts and 2 physics education lecturers. The purpose of this study was to determine the level of student assessment of distance learning using TEALSim by lecturers in introductory courses in quantum physics. In addition, researchers also want to know the correlation between student perceptions and learning outcomes.

The research procedure carried out was divided into 8 steps, namely (1) Conducting an initial study of the distance learning format for physics education students, (2) Conducting an analysis of the product to be developed in the form of a TEALSim-based learning device. (3) Initial product development in the form of TEALSim, test instruments and questionnaires on student perceptions of learning. 4) Expert validation and revision of TEALSim, materials in TEALSim, test instruments, and questionnaires on student perceptions of learning, 5) Small-scale limited trials and product revisions, 6) Giving initial tests of students' understanding of

the concept of wave-particle dualism, (7) Field trials by applying the TEALSim-based learning tool on the concept of wave-particle dualism, (8) at the end of the lesson students do the final test and also fill out a student response/perception questionnaire on the learning that has been done.

The study population was students who programmed introductory quantum physics courses at Makassar State University, totaling 185 students. Sampling using simple random sampling technique with 26 students as the sample. This study uses a One Shoot Case Study design. In this study, there was a group of students who were given treatment in the form of applying TEALSim in distance learning physics 3 times. Then, at the end of learning students are asked to fill out a survey using the Google form. Furthermore, as the final part of the research, students were asked to complete a learning achievement test.

The data collection techniques used were questionnaires and tests. The questionnaire made using google form contains several questions related to student assessments of the media and learning processes that have been used with several indicators. The questionnaire obtained through coding the respondent's assessment was then analyzed descriptively quantitatively by calculating the percentage of responses and then depicted the level of radiation of the analysis results based on the perception scale. Meanwhile, the test is in the form of a description given to students after the wave-particle dualism material has been taught by the lecturer using TEALSim in distance learning. Data analysis used an independent sample t-test to find out how much the benefits of TEALSim teaching materials in distance learning. Parametric statistics are used when the data is normally distributed. To test the research hypothesis used Product Moment correlation analysis (Amin et al., 2019; Amin & Mahmud, 2016).

Results and Discussion

Student perception questionnaires, test instruments, and learning instruments based on TEALSim that have been developed are then validated by experts before use. The student perception questionnaire consists of several aspects and each aspect has several questions. The aspects of the student perception questionnaire are (1) the appearance and content of TEALSim, (2) Self-regulated learning with TEALSim, (3) The attractiveness of TEALSim teaching materials, and (4) Learning activities with TEALSim. The test instrument used was in the form of multiple choices and a description consisting of 3 sub-concepts, namely (1) black body radiation, (2) photoelectric effect, and (3) Compton effect. Meanwhile, TEALSim-based teaching materials consist of a guidebook for the use of TEALSim, student worksheets, and the TEALSim application in which there are video observation instructions, videos on physics concepts, and interactive simulations as a substitute for observations in a virtual laboratory. TEALSim is also connected to e-learning which helps students communicate with lecturers and also facilitates assignment collection and evaluation. The following is a display of one of the simulations from TEALSim.
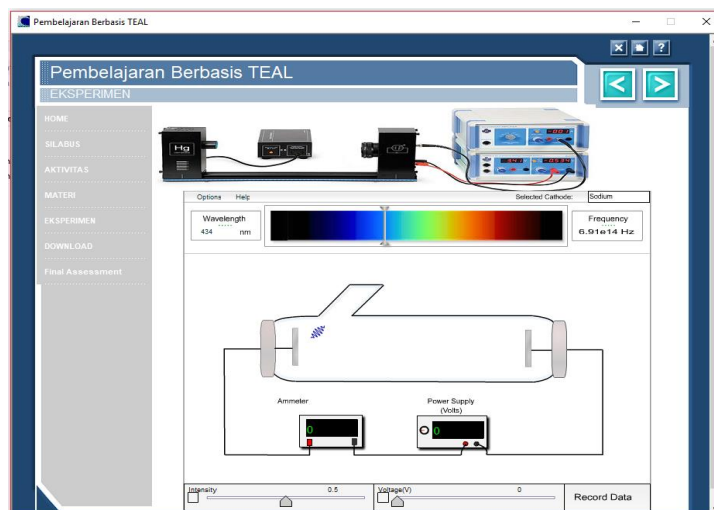
Figure 1. Display of the photoelectric effect experiment on TEALSim

Figure 1 is a display of the photoelectric effect experiment in the TEALSim application. This application has 7 menus, namely (1) "home" contains a brief description of the application, accessible teaching materials, virtual experiment modules, and video tutorials on the implementation of learning with TEALSim, (2) "syllabus" contains the expected learning outcomes in each sub material, (3) "activity" contains a complete description of the implementation of learning, learning steps with the Technology-Enabled Active Learning Simulation are presented in full in this section, (4) "material" contains theories or concepts related to the subject, in this menu also students can access many learning resources both books and instructional videos, (5) "experiments" which contain 3 virtual experiments each of which are black body radiation, photoelectric effect, and Compton effect. Virtual experiments (simulations) are adopted from open-source sources on the internet and developed by adding various image features and then assembled so that they can describe the same arrangement of tools in real laboratories, (6) "Download", on this page contains applications or supporting software needed in using TEALSim including adobe flash player, (7) the "Assessment" menu contains a collection of questions and discussions related to the material. In addition, TEALSim is also connected to the Edmodo application platform. On this platform, lecturers control learning, interact with students where there is a chat feature similar to social media, lecturers can also update information about online learning and students can easily get notifications through the Edmodo application on their smartphones. The TEALSim application and its supporting teaching materials, perception instruments, and comprehension test instruments developed have been valid and reliable and then applied in learning. The data obtained from the perception questionnaire using the form was automatically analyzed in order to obtain the percentage of student perceptions. In addition, the data obtained for the conceptual understanding test on 3 sub-materials which include black body radiation, photoelectric effect, and Compton effect are averaged. The results of the analysis are as in the table below:

Table 1. Results of The Analysis

No	Student ID	Test Score	Perception (%)
1	1612040002	90.4	94.6
2	1612040004	54.8	81.1
3	1612040006	89.1	94.6
4	1612040008	89.1	93.2
5	1612040012	84.9	93.2
6	1612040018	86.3	94.6
7	1612040020	68.3	77.7
8	1612040022	75.2	81.1
9	1612041002	72.5	87.8
10	1612041004	76.2	95.3
11	1612041006	73.9	93.9
12	1612041008	73.9	93.9
13	1612041010	64.9	81.1
14	1612041012	75.2	81.8
15	1612041014	76.5	82.4
16	1612041016	91.7	90.5
17	1612041018	90.4	94.6
18	1612042002	75.2	81.1
19	1612042006	65.5	75.7
20	1612042008	79.1	85.8
21	1612042010	87.8	97.9
22	1612042012	62.9	74.3
23	1612042014	77.9	77.7
24	1612042016	70.0	78.4
25	1612042018	73.9	75.0
26	1612042022	73.8	81.1
Average		76.9	86.1

Based on the data in the table, it can be seen that the average percentage of student perceptions of the learning process that has taken place with TEALSim is at a value of 86.09% which is in the very good category (strongly agree). This is in line with the research conducted by Yusuf and Widyaningsih which stated that the implementation of physics learning based on virtual laboratories such as interactive simulations has a positive effect on science process skills and student perceptions are in the very good category (Irfan Yusuf dan Sri Wahyu Widyaningsih, 2018). Shie argues that there is a positive influence on the use of Technology-Enabled active learning on students' mastery of concepts, both male and female. Most users strongly agree and are satisfied with the implementation of learning with TEAL (Shieh, 2012). Furthermore, from the table above then grouped by category or gradation. The distribution is as below.
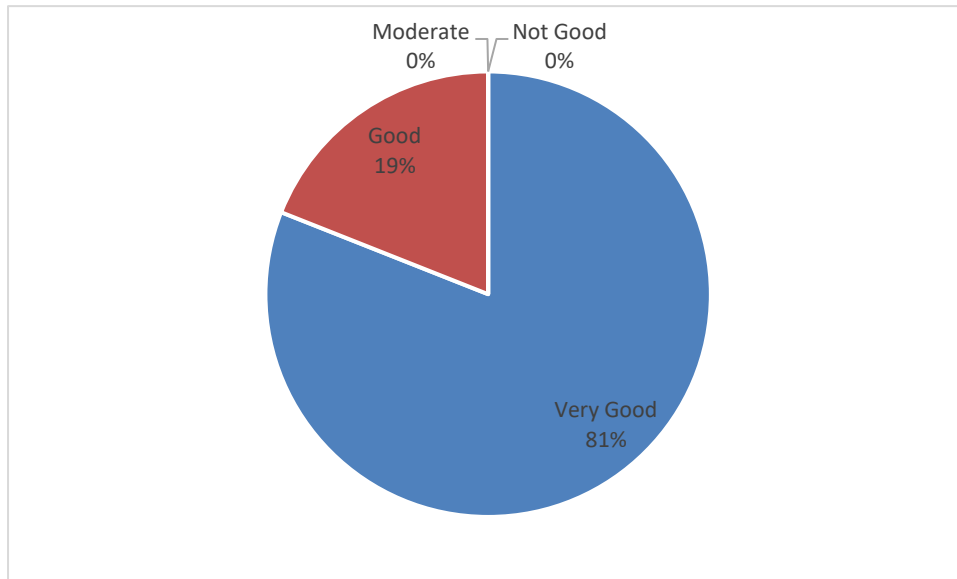
Figure 2. Perception category grouping

Based on the graph, there are 81% or the equivalent of 21 students giving very good assessments and 19% or 5 students giving good assessments. Therefore, it can be concluded that students strongly agree with the use of TEALSim teaching materials in supporting distance learning. The use of simulations through active learning has also responded positively to students in Australia. The Active Learning Classroom generated very positive responses from both instructors and students. more than 85% of students recommend Active Learning Classrooms to other classes. Instructors and students are well aware that this space makes a difference for them (Fisher, 2010).

Based on the comments given by students, there are several points can be concluded that (1) students are very happy to use TEALSim because they can observe abstract phenomena even though only through interactive simulation media. (2) With a video about the guidelines for using TEALSim, it is very helpful in the experimental process virtually. Step by step is explained in detail via video. (3) The TEALSim display and the content in it are complete enough so that they have freedom in learning, especially having a wide selection of learning resources. (4) The majority of students also agreed with the use of TEALSim in combination with instructional videos made directly by the lecturer. Learning becomes interesting, not monotonous, and able to make students more active and solve existing problems. This is in line with the opinion of Gunawan et al which states that the application of a virtual laboratory containing interactive simulations improves problem-solving for prospective physics teachers (Gunawan, Harjono, & Sahidu, 2015; Sarı, Hajiomer, Güven, & Faruk, 2017). Students are very happy because they can still do experimental activities even though they are at their respective homes. So far, for basic physics learning, they make direct observations in the laboratory. Some students prefer the virtual lab in this study called TEALSim because there is almost no risk that occurs compared to the hands-on lab.
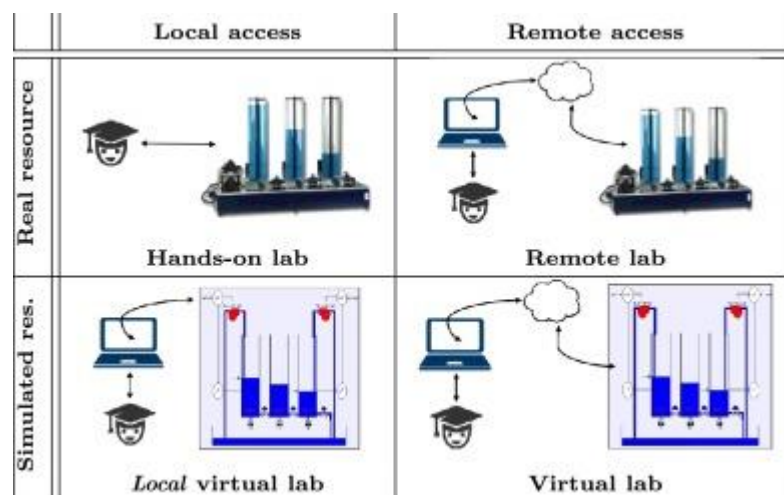
Figure 2. Types of laboratories based on the method and place of use.

Figure 2 is the types of labs based on where and how to use the lab. Labs that are accessed locally and carried out directly by students in the laboratory are called hands-on labs. Then the remote lab is a lab that is accessed by students via a computer, where there are users who conduct experiments directly in the laboratory and can be observed online the experimental process. Also, laboratories in the form of software or interactive simulations that are stored and accessed using a computer directly by the user are called local virtual labs. And the last is virtual and remote labs that are accessed via the internet, in other words, software that is accessed remotely. This virtual and remote lab is very suitable for use at this time because the simulation software on the website or online learning platform is easy to use, besides that lecturers can still provide instructions during learning. But of course, the use of this learning format still has some problems.

Several suggestions and criticisms were given by students related to the use of TEALSim to support distance learning. Some of these points are summarized by the researchers as follows, (1) videos in the TEALSim application need to be edited and converted so that the quality and capacity are reduced so that the application is easier to use and download by students even though the network quality is not good. (2) some students still find it difficult to analyze with Excel, it is better if the lecturer provides a pdf file that can be used as a guide for analyzing the results of virtual experiments using Excel. (3) some students also suggested that the display size of the TEALSim application adjusts to the size of the laptop used by students. (4) Some of the biggest obstacles experienced by students are limited access to internet networks and supporting technology so that the online learning platform and TEALSim are very difficult for students to access. This problem is faced by almost all students who live in remote areas. This is not only happening in Indonesia but also abroad. This is in accordance with Ghaviker's opinion that the lack of adequate ICT equipment and internet access is one of the main problems facing schools, especially in rural areas today (Ghavifekr & Rosdy, 2015).

Before doing a correlation test between student perceptions and learning outcomes, a data normality test was conducted to determine whether the data distribution was normal or not. Based on the results of the data normality test, the value was 0.201. This shows that this value is greater than the value of 0.05, so it can be concluded that the data obtained is

normally distributed (Gunawan et al., 2015). Furthermore, a correlation test was carried out between students 'perceptions of the use of TEALSim in physics learning and its impact on students' mastery of concepts. The correlation test carried out between the student's perception variable and concept mastery obtained a value of 0.721 which was in the good category. Therefore, it can be concluded that there is a good correlation between the two variables. Several studies support the results obtained in this study, such as those conducted by Yusuf and Widyaningsih, who state that there is an effect of using interactive simulation-based applications on student learning outcomes and critical thinking skills (Yusuf & Subaer, 2013). Sari et al stated that student learning outcomes improved after using interactive simulations. In addition, students' attitudes are also in the good category (Sarı et al., 2017). The same thing was done by Hensberry, who stated that there was an effect of the use of interactive simulations on student learning outcomes and attitudes in learning mathematics. Besides, research conducted by Srisawasdi shows that middle school students have better conceptual science achievement by interacting with inquiry-based science learning with simulations. These findings suggest and could be argued, that the use of simulations in secondary education could be used to enhance students' conceptual development of science concepts and their understanding (Srisawasdi & Panjaburee, 2015).

Conclusion

Based on the results of research and data analysis, it shows that students' perceptions of the use of TEALSim in distance learning for the introductory course in quantum physics are very good with an assessment percentage of 86.09%. Meanwhile, based on the correlation test, it can be concluded that there is a fairly good relationship between students 'perceptions of using TEALSim and students' mastery of concepts. This is indicated by a correlation value of 0.7. Based on the conclusions, it can be said that the use of TEALSim can increase student activeness in distance learning which has an impact on concept mastery.

The results of this study cannot be generalized in general, this is due to the small number of samples and then the researcher does not control for other variables that work. Therefore, further research needs to be developed for other materials. In addition, the number of samples needs to be added and other research methods that have high validity need to be done.

Credit Authorship Contribution Statement

Ahmad Swandi: Conceptualization, Methodology, Visualization, Formal analysis, Investigation, Data Curation, Writing – original draft. **Sri Rahmadhanningsih**: Methodology, Formal analysis, Resources, Writing – review & editing, Investigation, Project administration. **Sparisoma Viridi**: Validation, Software, Formal analysis, Resources, Supervision, Project administration.

References

Ahmad, I. F. (2020). Alternative Assessment in Distance Learning in Emergencies Spread of Coronavirus Disease (COVID-19) in Indonesia. *Jurnal Pedagogik*, *7*(1), 195–222.

Ahmad, S., & Bunga, D. A. (2015). Pengembangan Media Simulasi Interaktif Berbasis Web untuk Meningkatkan Aktivitas Belajar Peserta Didik. *Prosiding Pertemuan Ilmiah*

XXIXHFI Jateng & DIY, (April), 192–195.

Amin, B. D., Haris, A., & Swandi, A. (2019). Implementation of Physics Learning Based on Hypermedia To Enhance Student'S Problem Solving Skill. *International Journal of Teaching & Education*, *VII*(2), 1–11. https://doi.org/10.20472/te.2019.7.2.001

Amin, B. D., & Mahmud, A. (2016). The Development of Physics Learning Instrument Based on Hypermedia and Its Influence on the Student Problem Solving Skill. *Journal of Education and Practice*, *7*(6), 22–28.

Dushkevych, M., Barabashchuk, H., & Hutsuliak, N. (2020). Peculiarities Of Student Distance Learning In Emergency Situation Condition. *Revista Romaneasca Pentru Educatie Multidimensionala*, *12*(1Sup2), 71–77. https://doi.org/10.18662/rrem/12.1sup2/248

Fisher, K. (2010). *CELE Exchange, Centre for Effective Learning Environments Technology-Enabled Active Learning Environments: An Appraisal*.

Ghavifekr, S., & Rosdy, W. A. W. (2015). Teaching and learning with technology: Effectiveness of ICT integration in schools. *International Journal of Research in Education and Science*, *1*(2), 175–191. https://doi.org/10.21890/ijres.23596

Gunawan, Harjono, A., & Sahidu, H. (2015). Pengembangan Model Laboratorium Virtual Berorientasi Pada Kemampuan Pemecahan Masalah Bagi Calon Guru Fisika. *Prosiding Seminar Nasional Fisika Dan Pendidikan Fisika (SNFPF)*, *6*(1), 232–237.

Hartikainen, S., Rintala, H., Pylväs, L., & Nokelainen, P. (2019). The concept of active learning and the measurement of learning outcomes: A review of research in engineering higher education. *Education Sciences*, *9*(4), 9–12. https://doi.org/10.3390/educsci9040276

Hassan, N. F. B., Puteh, S. Bin, & Muhamad Sanusi, A. B. (2018). Elements of Technology Enabled/Enhanced Active Learning (TEAL) to Enhance Quality and Employability of Bachelor's Students. *MATEC Web of Conferences*, *150*, 4–11. https://doi.org/10.1051/matecconf/201815005005

Irfan Yusuf dan Sri Wahyu Widyaningsih. (2018). Laboratorium Virtual Terhadap Keterampilan Proses sains dan persepsi mahasiswa. *Inovasi Pendidikan Fisika*, *6*(1), 18–28.

Krišťák, Ľ., Němec, M., & Danihelová, Z. (2014). *Interactive Methods Of Teaching Physics At Technical Universities. Ľuboš Krišťák, Miroslav Němec, Zuzana Danihelová*. *13*(1), 51–71.

Mastorodimos, D., Chatzichristofis, S. A., Jimoyiannis, A., & Christodoulou, K. (2018). Making Sense of Fractions using E-learning Platforms-A Survey. *2018 IEEE (SMC) International Conference on Innovations in Intelligent Systems and Applications, INISTA 2018*, (February 2019). https://doi.org/10.1109/INISTA.2018.8466304

Napitupulu, R. M. (2020). Dampak pandemi Covid-19 terhadap kepuasan pembelajaran jarak jauh. *Jurnal Inovasi Teknologi Pendidikan*, *7*(1), 23–33. https://doi.org/10.21831/jitp.v7i1.32771

Palloan, P., & Swandi, A. (2019). Development of learning instrument of active learning strategy integrated with computer simulation in physics teaching and learning on makassar state university. *Journal of Physics: Conference Series*, *1157*(3). https://doi.org/10.1088/1742-6596/1157/3/032016

Perdana, I., Eria, R., Saragi, S., Aribowo, E. K., Raya, U. P., Widya, U., & Klaten, D. (2020). *Students ' Perception of Utilizing Kahoot In Indonesian Language Learning*. *08*(02), 290–306.

Santi Maudiarti. (2018). Penerapan E-Learning Di Perguruan Tinggi. *PERSPEKTIF Ilmu Pendidikan*, *32*(1), 53–68.

Sarı, U., Hajiomer, A., Güven, K., & Faruk, Ö. (2017). Effects of the 5E Teaching Model Using Interactive Simulation on Achievement and Attitude in Physics Education. *International Journal of Innovation in Science and Mathematics Education*, *25*(3), 20–35.

Sen, S., & Oskay, O. O. (2016). The Effects of 5E Inquiry Learning Activities on Achievement and Attitude toward Chemistry. *Journal of Education and Learning*, *6*(1), 1. https://doi.org/10.5539/jel.v6n1p1

Shieh, R. S. (2010). The impact of technology-enabled active learning on student performance, gender and achievement level. *CSEDU 2010 - 2nd International Conference on Computer Supported Education, Proceedings*, *2*, 420–425. https://doi.org/10.5220/0002783504200425

Shieh, R. S. (2012). The impact of technology-enabled active learning (TEAL) implementation on student learning and teachers' teaching in a high school context. *Computers and Education*, *59*(2), 206–214. https://doi.org/10.1016/j.compedu.2012.01.016

Srisawasdi, N., & Panjaburee, P. (2015). Exploring effectiveness of simulation-based inquiry learning in science with integration of formative assessment. *Journal of Computers in Education*, *2*(3), 323–352. https://doi.org/10.1007/s40692-015-0037-y

Subekti, Y., & Ariswan, A. (2016). Pembelajaran fisika dengan metode eksperimen untuk meningkatkan hasil belajar kognitif dan keterampilan proses sains. *Jurnal Inovasi Pendidikan IPA*, *2*(2), 252. https://doi.org/10.21831/jipi.v2i2.6278

Swandi, A., Amin, B. D., Viridi, S., & Eljabbar, F. D. (2020). Harnessing technology-enabled active learning simulations (TEALSim) on modern physics concept. *Journal of Physics: Conference Series*, *1521*(2). https://doi.org/10.1088/1742-6596/1521/2/022004

Swandi, Ahmad, Nurul, S. H., & Irsan. (2015). *Pengembangan Media Pembelajaran Laboratorium Virtual untuk Mengatasi Miskonsepsi Pada Materi Fisika Inti di SMAN 1 Binamu, Jeneponto (Halaman 20 s.d. 24)*. *18*(52), 20–24. https://doi.org/10.22146/jfi.24399

Yusuf, I., & Subaer. (2013). Pengembangan perangkat pembelajaran fisika berbasis media laboratorium virtual pada materi dualisme gelombang partikel di sma tut wuri handayani Makassar. *Jurnal Pendidikan IPA Indonesia*, *2*(2), 189–194. https://doi.org/10.15294/jpii.v2i2.2722