ISSN 2964-4291
https://proceeding.unnes.ac.id/index.php/iset

Meta-Analysis of Student Reality Construction in Online Practicum

Yusmaniar Afifah Noor*, Ngurah Made Darma Putra, Sunyoto Eko Nugroho

Universitas Negeri Semarang, Postgraduate Physics Education, Indonesia
Corresponding Author: yusmaniarafifah01@students.unnes.ac.id

Abstract. The absence of ideal characteristics from the use of practicum can be solved based on empirical data which makes the practicum more effective. Reality construction is a way of taking pictures based on what students get from practical experience. The purpose of this study is to identify indicators of reality construction formed by students in online practicums. The method used is a meta-analysis by reviewing 24 international journals. The data analysis used is quantitative data analysis with effect size and percentage, while qualitative data analysis is for data resulting from narrative studies of the studies encountered. Based on analysis study of reality construction indicators can be generated five indicators that often appear, which is conceptual understanding, relevance and contribution of laboratory activities, student satisfaction, interaction and laboratory work patterns, resources and instructional. Students' conceptual understanding can be increased by applying online practicum. More than 60% of respondents stated that the contribution of online practicum is the same or better than conventional practicum. Overall, students feel quite satisfied in accessing online practicum, especially satisfaction in terms of time. However, students have more difficulty collaborating in online practicums. Along with the development of digital technology can facilitate interaction by communicating virtually. In addition, adequate quality of resources and instructional resources are needed so that they can effectively frame student learning.

Key words: meta-analysis; reality construction; online practicum.

How to Cite: Noor, Y.A., Putra, N.M.D., Nugroho, S.E. (2021). Meta-Analysis of Student Reality Construction in Online Practicum. *ISET: International Conference on Science, Education and Technology, 7*(1), 674-684.

INTRODUCTION

Education is a very important activity for humans, because it can change behavior and knowledge for the better. Education is the main learning service offered to future generations, so the purpose of education must meet the demands of a changing world (Astalini et al., 2019; Bao & Koenig, 2019). The purpose of education has evolved, not only the end result is considered but also required to understand the learning process. Learning theory is increasingly emphasizing the active and meaningful learning process in learning situations. Students are required to be centered in the learning process and the teacher as a facilitator. An important part of the learning process is compiling knowledge and connecting with previous knowledge (Beerenwinkel & Arx, 2017). Structured and well-organized knowledge is also important for problem solving (Boisandi & Darmawan, 2017). Hierarchically structured knowledge can improve accessibility as well as show relevant details in working memory storage.

The world is currently faced with the Covid-19 pandemic which has changed many sectors, especially the education sector. The current educational process is shifting from face-to-face learning to online learning. Characteristic of online learning is the separation between students and teachers and other students in the learning process. The development of digital technology makes online learning easier to implement (Schröder-Turk & Kane, 2020). The physics learning process does not only require students to memorize concepts, but students are required to understand and apply these concepts (Aminudin et al., 2019). Physics learning emphasizes providing direct experience to develop competencies and skills.

The application of practicum in physics learning has an important role, which is to deepen understanding and application of concepts (Panuluh et al., 2020). Physics learning cannot be learned meaningfully without practical experience in the laboratory (H. O. Kapici et al., 2019). Laboratory experiences provide opportunities for students to build their own knowledge through experimentation. The implementation of the practicum can be done in various ways so that it remains carried out during the online learning process. The variations of the practicum used by the teacher include virtual laboratories, demonstrations and hands-on (Noor et al., 2020).

The application of practicum can create interactive learning that will have a motivational effect by creating a sense of responsibility and allowing students to play an active role in the learning process. The practicum process involves textual and visual information that can activate the sensory system and provide a more realistic and authentic approach for students. Component combination of verbal and writing may lead to a better processing within a limited working memory (Chiu & Hew, 2018). Practical implementation in physics learning is an inseparable part.

Practical application is needed so that students are able to construct understanding directly. Practicum in the physics learning process can improve student performance, especially in aspects of knowledge, process skills and student attitudes (Asrizal et al., 2018). However, there is no agreement on the ideal characteristics and use effects of laboratory experience. This lack of agreement can be resolved with better empirical data on what makes the practicum effective. Reality construction is a way of taking pictures based on what students get, the understanding that students get during the practicum.

METHOD

Research Goal

The purpose of this research is to identify the indicators of reality construction that are formed by students in the implementation of practicum.

Sample and Data Collection

This study uses a meta-analysis method by reviewing several journals. Meta-analysis can be done by comprehensive analysis of a number of journals from several research results on the chosen topic. The instrument used is a human instrument. After the focus of the research becomes clear, it will be developed into a simple instrument that is expected to be able to complete the data and compare the data that has been found previously. Data collection technique used documentation techniques. The population in this study is an international journal of "online lab or lab remotely" in 2000-2020. The research sample was taken using a purposive sampling technique taken as many as 24 international journals.

Analyzing of Data

The data analysis used is quantitative data analysis with effect size and percentage, while qualitative data analysis is for data resulting from narrative studies of the studies encountered. The research procedure used in this study was adapted to the steps for conducting a meta-analysis according to Wilson & Kelley (Anggreni et al., 2019), namely: 1) Determine the topic to be researched. The topic studied in this study is the construction of reality that is formed in the implementation of online learning practicum. 2) Determine the period of research results that are used as data sources. In this study, the selected period is 2000-2020. 3) Looking for research journals related to the topic to be researched. 4) Read the titles and abstracts of various journals to see the suitability of the contents with the problem to be studied. 5) Focusing research on problems, methods, populations, samples, data collection techniques, data analysis and results. 6) Categorize each journal. 7) Comparing the results of all studies according to the category. 8) Analyze the conclusions found by reviewing research results by reviewing methods and data analysis in each study so that the strengths and weaknesses of previous research can be known. 9) Write conclusions.

RESULTS AND DISCUSSION

Practicum is a component of science education which is believed to be able to provide direct experience and make students active in the learning process. The absence of agreement on the ideal characteristics of the laboratory experience can be resolved by empirical data on what makes practical’s effective. Empirical data that students build based on what they have obtained during practicum is called reality construction. Based on the analysis of reality construction indicators on 24 journals, five indicators that often appear are produced. Reality construction indicators can be seen in Table 1.

Table 1. Reality Construction Indicators formed by Students in Practicum

No	Reality Construction Indicators	Frequency	Percentage
1.	Concept mastery	18	75
2.	Relevance and Contribution of Laboratory Activities	12	50
3.	Student satisfaction	17	71
4.	Interaction and laboratory work patterns	9	38
5.	Resources and instructional	4	17

Table 1 shows the indicator that most often appears is the mastery of concepts as much as 75%. Mastery of concepts is important to measure to determine the extent to which the cognitive constructs formed by students during the practicum process. Another aspect that needs to be measured is the relevance and contribution of laboratory activities and student satisfaction to determine the perceptions formed by students during the practicum. Meanwhile, resources and instructions are also important to measure to determine the effect of the supporting components during practicum activities.

Concept Mastery

Laboratory practicum is seen as an important tool in science learning. The role and quality of learning outcomes achieved from laboratory activities are research subjects that are often studied. One aspect that is assessed in laboratory activities is the concept mastery gained during practicum activities. Concept mastery was assessed using a cognitive test instrument. The test is carried out before the implementation (pre-test) and after the implementation of the practicum (post-test). An important knowledge test is carried out to determine the cognitive constructions formed by students during the practicum process. The learning outcomes of students' cognitive domains with an online practicum format can be seen in Table 2.

Table 2. Category Effect Size Effect of Online Practicum on Concept Mastery

No	Title	Year	Effect Size	Category
1.	Constructing Reality: A Study of Remote, Hands-On and Simulation Laboratorium	2007	1.47	High
2.	Remote versus hands-on labs: a comparative study	2004	0.60	Medium
3.	Using Hands-on and Virtual Laboratories Alone or Together—Which Works Better for Acquiring Knowledge and Skills?	2019	1.25	High
4.	Process and learning outcome from remotely-operated, simulated, and hands-on student laboratories	2011	2.66	High
5.	Getting real: the authenticity of remote labs and simulations for science learning	2013	1.69	High
6.	Are Virtual Labs as Effective as Hands-on Labs for Undergraduate Physics? A Comparative Study at Two Major Universities	2014	2.45	High
7.	Physical versus virtual manipulative experimentation in physics learning	2011	2.41	High
8.	Pedagogical evaluation of remote laboratories in eMerge project	2007	0.61	Medium
9.	A case study for comparing the effectiveness of a computer simulation and a hands-on activity on learning electric circuits	2015	0.69	Medium

Recapitulation the effect of online practicum on concept mastery in nine studies, there are three studies with effect size in the medium category and six studies in the high category. Based on Table 2, it can be concluded that there is an effect of using online practicum on students' mastery of concepts. Student learning outcomes show that online practicums work well for understanding concepts related to laboratory topics. This is in accordance with the research of Prima et al. (2018) the use of bold practicums in the science learning process can improve students' conceptual understanding. Implementation of an online lab can significantly increase students' understanding of the concept of practical content (Post et al., 2019). In addition, the use of a virtual laboratory provides concept mastery results that are as good as conventional practicums (Faulconer & Gruss, 2018) and minimizes student misconceptions in physics learning (Diani et al., 2018). Students' conceptual understanding based on the posttest results was significantly better than the pretest results, but there was no significant difference between students using online practicum and conventional practicum (Post et al., 2019). This shows that online practicums can be a valuable tool and provide services that are as good as conventional practicums.

The attention of students in conventional practicums is understanding the procedures to be carried out and the use of practicum equipment, so students are less focused on developing a conceptual understanding of how data and concepts are relevant to the practicum they are doing (Nolen & Koretsky, 2018; Puntambekar et al., 2020). While in the online practicum, students explore the experimental data one by one, so that students have more opportunities to set up experiments, vary parameters, observe effects, so that students can develop a deeper understanding. Overall, it shows that the use of online practicum is better in increasing students' understanding of the physics concepts being studied (Sutarno et al., 2017).

Relevance and Contribution of Laboratory Activities

The relevance and contribution of laboratory activities is important to determine the relevance and contribution of online practicums in supporting learning objectives. The relevance and contribution of laboratory activities include the relevance of learning materials, the usefulness of practicum implementation and contributions to use of scientific methods.

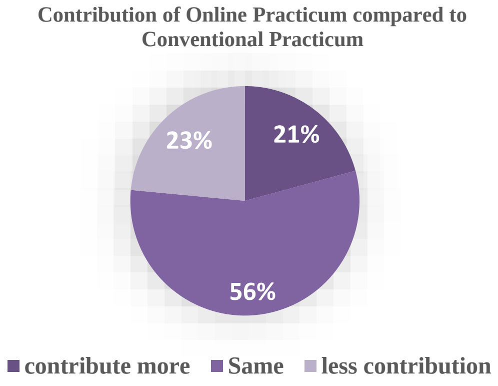

Figure 1. Contribution of Online Practicum compared to Conventional Practicum

Figure 1 shows that more than 60% of respondents stated that the online practicum had the same or better contribution compared to the conventional practicum. Online and conventional practicums have the same relevance to the learning topic. There is no significant difference in the relevance of practicum material with learning topics, where hands-on and virtual laboratories provide the same benefits (Steger et al., 2020). This is in accordance with the opinion of Kapici et al. (2021) which states that online and conventional practicums have the same advantages and effectiveness in the learning process.

Laboratory practicum activities provide opportunities for students to build their own knowledge by experimenting. In addition, the advantage of an online laboratory is that it can see phenomena that cannot be seen in the real world that can be observed in a virtual laboratory (Mirçik & Saka, 2018; Correia et al., 2019). Students who apply practical work using virtual laboratories can focus more on the main concepts and minimize students' focus on irrelevant information (Menéndez et al., 2019). Students will focus more on experimental data to be obtained without having to have difficulty in preparing tools and materials (Masril et al., 2018).

Online practicum allows students to be more flexible in data collection and can learn abstract concepts better from animations in interesting relevant concepts from an experiment (Menéndez et al., 2019). In addition, the application of online practicum makes it easier for students to take data, analyze data and write conclusions (Rowe et al., 2018). Online practicums can be repeated according to student needs, so as to further increase knowledge of learning materials. Significantly the application of virtual laboratory can improve students' conceptual understanding and can increase students' learning motivation (Khaerunnisak, 2018). Students who apply online practicum will be encouraged to better understand the concept of the material in detail and the speed of learning according to their abilities. Application of practicum can help students to overcome the limitations of working memory and helps to make the process may not be able to do for themselves. The application of virtual laboratories can increase students' curiosity and interest in the learning process and enable students to develop higher-order thinking skills (Galan et al., 2017).

Student Satisfaction

Student satisfaction is interesting to consider to find out the experiences felt by students during practicum. The experience by students in conducting practicum provides actual content and psychomotor tools related to its completion so that it can have an impact on other skills (Brinson, 2015). Student satisfaction includes the accessibility of practicum use, time required, clarity of content and convenience in scheduling practicums.

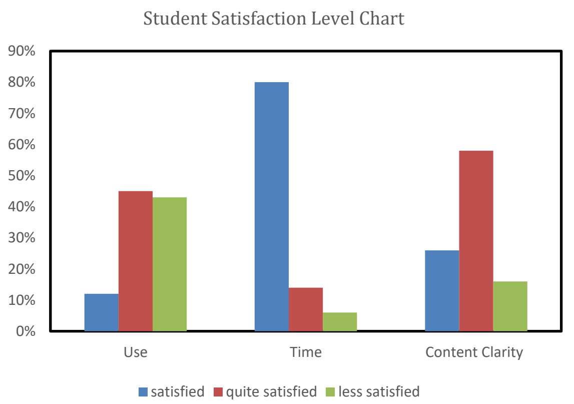

Figure 2. Graph of Student Satisfaction Level

Figure 2 shows the perception of students most striking advantage of using an online lab that time satisfaction levels. Online practicum can be accessed with less time than conventional practicum which can only be accessed during certain lesson hours. Students feel free to manage when and where to access online practicums. In addition, students can repeat the parts that they feel do not understand so that the level of speed and time of use of each student is different.

Figure 2 shows that more than 60% of students feel sufficient or satisfied in the clarity of the content and more than 50% of students feel sufficient or satisfied in the use of online practicum. Students feel enjoy and feel content in an online lab is already clear, though students find it difficult at the beginning of the workings of the lab because there is no friend or teacher directly who can be consulted (Viegas et al., 2018). Overall, students feel quite satisfied in accessing the online practicum. Students feel that the use of online practicums has been implemented well, with the most common reason being that online practicums meet the different learning needs of students and can provide greater motivation and interest for students and support high flexibility for the student learning process (Menéndez et al., 2019). Online practicum in physics learning can help students increase their verbal and figural creativity higher than conventional practicum (Gunawan et al., 2017). Students feel that the use of online practicums emphasizes better theoretical goals than conventional practicums (Gunawan et al., 2018; Efstathiou et al., 2018).Understanding of concepts formed by students is better because the speed in the practicum process is controlled by themselves.

Interaction and laboratory work patterns

Interaction is one of the components that determine students' critical abilities and encourage the improvement of active learning processes (Kyei-Blankson et al., 2016). Interaction can be identified into two contexts, namely individual and social. Individual context refers to the interaction between students and learning materials. Social context refers to the interaction between two or more people with learning content. Important determinant of interactive online learning success includes the level of student participation. Interaction can help bridge communication gaps and misconceptions of material in online practicums. Separation between students and teachers and other students characterize the lab process online, so the interaction is a problem often encountered.

One of the obstacles to online practicums is that students often do not interact socially so they do not have the opportunity to share information. Students have more difficulty collaborating in online practicums than conventional practicums. Students feel that their geological separation from other group members and also from laboratory equipment makes collaboration more difficult. Research by Lowe et al. (2013) showed that 47% of students felt less effective in implementing group work in the online practicum process compared to conventional practicums. Students tend to be in one room more often when collecting research data in conventional practicums compared to online practicums. Without communication students are exposed to a very strong sense of isolation. To overcome this sense of detachment, there is a need to implement social interactions where students can interact with peers, discuss their findings, help each other and collaborate. This is in accordance with the results of Husnaini & Chen (2019) research that accurately reflects the scientific method in the real world, such as scientists, so students are given more opportunities and time to interact and discuss their ideas.

Students who use an online practicum will find a different way when interacting and collaborating with peers. Most of the students think that doing online practicum separately with colleagues and discussing with group friends and teachers online (Wei et al., 2019). While the research of Corter et al. (2007) showed 74% of students collected data separately and not all students were involved in data acquisition. Some students argue delegate data collection to their group of friends. These findings suggest that assessment is needed to ensure full participation by each group member. The interaction between students with peers and teachers has a major contributor to collaboration and practicum performance.

Student social interaction can support collaborative learning theory. Student involvement in group work has a significant effect on increasing students' mastery of concepts, skills and perceptions (Chen et al., 2018). Research Corter et al. (2011) shows that interaction helps students in building identity in the data stage and jointly coordinates laboratory procedures, with good interaction collaboration will be established between them. The development of digital technology today can facilitate student interaction and communication. Research Broisin et al. (2017) shows that students do not meet face-to-face in completing the practicum, but they communicate virtually using mobile phones. Successful collaboration requires the sharing of knowledge and data information. Maximum group work patterns can increase social interaction, motivation and produce a better understanding of concepts.

Resources and Instructional

Resources and instruction are indispensable in the online practicum process. Resources include things that are needed to support the implementation of the practicum, such as tools and practicum materials and the internet network. While instructional includes worksheets and directive instructions given by the teacher to students in carrying out practicum. The success rate of online practicum is very dependent on the tools and supporting materials. Adequate quality of resources and instructional can frame student learning effectively. Many students do not understand the instructions given about operating technology in online practicums, so students really need help from teachers and student worksheets to make it easier to operate the practicum (Lima et al., 2019).

The application of online practicum is a new thing for students and teachers. Educators must gradually introduce online practicums to students and prepare relevant and better resources and instructional resources in the future. Properly giving worksheets and teacher support will make online practicum more effective (Falloon, 2019). Most students positively accept the development of online practicums in terms of functionality, students feel that the resources provided in online practicums are good enough, but there are obstacles if inadequate internet quality can cause delays and hinder the implementation of practicums (Noor et al., 2020). The success of students in constructing understanding and carrying out practicum can’t be separated from the way the teacher provides directions for the implementation of the practicum. So it is important to analyze the way teachers provide resources and instruction in supporting the success of distance learning practicum.

CONCLUSION

Disagreements about the ideal characteristics of the experience of using practicum can be overcome with empirical data that students build based on what they get during online practicum. Reality construction is a way of taking pictures based on what students get, the understanding students get. Based on the analysis of reality construction indicators on 24 journals, five indicators that often appear, are concept mastery, relevance and contribution of laboratory activities, student satisfaction, interaction and laboratory work patterns, resources and instructional.

Based on the meta-analysis, it shows that the application of online practicum can improve students' conceptual understanding as well as conventional practicum. More than 60% of respondents stated that the online practicum had the same or better contribution compared to the conventional practicum. Overall, students feel quite satisfied in accessing online practicum, especially satisfaction in terms of time. Online practicum can be accessed with more flexible time and flexibility in managing when and where to access online practicum. In addition, students can repeat the part they feel they do not understand so that the speed in the practicum process is controlled by themselves. The problem that is often faced in online practicum is the interaction between students and other students and teachers. Students have more difficulty collaborating in online practicums than conventional practicums. However, the current development of digital technology can facilitate student interaction and communication by communicating virtually. In addition, resources and instructional also have an important role in the implementation of online practicum. Adequate quality of resources and instructional can frame student learning effectively.

ACKNOWLEDGEMENTS

This research was funded by the Postgraduate DIPA of Universitas Negeri Semarang in 2021 (Number: 96.19.5/UN37/PPK.5.1/2021)

REFERENCES

Aminudin, A. H., Rusdiana, D., Samsudin, A., Hasanah, L., & Maknun, J. (2019). Measuring critical thinking skills of 11th grade students on temperature and heat. *Journal of Physics: Conference Series*, *1280*(5), 1–5. https://doi.org/10.1088/1742-6596/1280/5/052062

Anggreni, Y. D., Festiyed, & Asrizal. (2019). Meta-Analisis Pengaruh Model Pembelajaran Project Based Learning terhadap Kemampuan Berpikir Kritis Peserta Didik SMA. *Pillar of Physics Education*, *12*(4), 881–888.

Asrizal, Hendri, A., Hidayati, & Fertiyed. (2018). Penerapan Model Pembelajaran Penemuan Mengintegrasikan Laboratorium Virtual dan Hots untuk Meningkatkan Hasil Pembelajaran Siswa. *Prosidimg Semonar Nasional Hibah Program Penugasan Dosen Ke Sekolah (PDS) Universitas Negeri Padang*, *November*, 49–57.

Astalini, Kurniawan, D. A., Perdana, R., & Kurniawan, W. (2019). Identification Attitudes of Learners on Physics Subjects.

Journal of Educational Science and Technology, *5*(1), 39–48. https://www.neliti.com/id/publications/177126/pengaruh-model-pembelajaran-dan-kesadaran-metakognitif-terhadap-hasil-belajar-pe

Bao, L., & Koenig, K. (2019). Physics education research for 21st century learning. *Disciplinary and Interdisciplinary Science Education Research*, *1*(2), 1–12. https://doi.org/10.1186/s43031-019-0007-8

Beerenwinkel, A., & Arx, matthias Von. (2017). Constructivism in Practice: an Exploratory Study of Teaching Patterns and Student Motivation in Physics Classrooms in Finland, Germany and Switzerland. *Research in Science Education*, 237–255.

Boisandi, & Darmawan, H. (2017). Meta Analisis Pengaruh Penerapan Pembelajaran Berbasis Konstruktivisme pada Materi Fisika di Kalimantan Barat. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *6*(2), 179–185.

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers and Education*, *87*(1), 218–237. https://doi.org/10.1016/j.compedu.2015.07.003

Broisin, J., Venant, R., & Vidal, P. (2017). Awareness and reflection in virtual and remote laboratories: The case of computer education. *International Journal of Technology Enhanced Learning*, *9*(2–3), 254–274. https://doi.org/10.1504/IJTEL.2017.084503

Chen, J., Wang, M., Kirschner, P. A., & Tsai, C. C. (2018). The Role of Collaboration, Computer Use, Learning Environments, and Supporting Strategies in CSCL: A Meta-Analysis. *Review of Educational Research*, *88*(6), 799–843. https://doi.org/10.3102/0034654318791584

Chiu, T. K. F., & Hew, T. K. F. (2018). Factors influencing peer learning and performance in MOOC asynchronous online discussion forum. *Australasian Journal of Educational Technology*, *34*(4), 16–28. https://doi.org/10.14742/ajet.3240

Correia, A. P., Koehler, N., Thompson, A., & Phye, G. (2019). The application of PhET simulation to teach gas behavior on the submicroscopic level: secondary school students' perceptions. *Research in Science and Technological Education*, *37*(2), 193–217. https://doi.org/10.1080/02635143.2018.1487834

Corter, J. E., Esche, S. K., Chassapis, C., Ma, J., & Nickerson, J. V. (2011). Process and learning outcomes from remotely-operated, simulated, and hands-on student laboratories. *Computers and Education*, *57*(3), 2054–2067. https://doi.org/10.1016/j.compedu.2011.04.009

Corter, J. E., Nickerson, J. V, Esche, S. K., & Chassapis, C. (2007). Constructing Reality : A Study of Remote , Hands-On , and Simulated Laboratories. *ACM Transactions on Computer-Human Interaction*, *14*(2), 1–27. https://doi.org/10.1145/1275511.1275513

Diani, R., Latifah, S., Anggraeni, Y. M., & Fujiani, D. (2018). Physics Learning Based on Virtual Laboratory to Remediate Misconception in Fluid Material. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *3*(2), 167. https://doi.org/10.24042/tadris.v3i2.3321

Efstathiou, C., Hovardas, T., Xenofontos, N. A., Zacharia, Z. C., DeJong, T., Anjewierden, A., & Riesen, S. A. N. van. (2018). Providing guidance in virtual lab experimentation: the case of an experiment design tool. *Educational Technology Research and Development*, *66*(Februari), 767–791.

Falloon, G. (2019). Using simulations to teach young students science concepts: An Experiential Learning theoretical analysis. *Computers and Education*, *135*(March), 138–159. https://doi.org/10.1016/j.compedu.2019.03.001

Faulconer, E. K., & Gruss, A. B. (2018). A review to weigh the pros and cons of online, remote, and distance science laboratory experiences. *International Review of Research in Open and Distance Learning*, *19*(2), 155–168. https://doi.org/10.19173/irrodl.v19i2.3386

Galan, D., Heradio, R., de la Torre, L., Dormido, S., & Esquembre, F. (2017). The experiment editor: supporting inquiry-based learning with virtual labs. *European Journal of Physics*, *38*(3), 035702.

Gunawan, G., Harjono, A., Sahidu, H., & Herayanti, L. (2017). Virtual laboratory of electricity concept to improve prospective physics teachers' creativity. *Jurnal Pendidikan Fisika Indonesia*, *13*, 102.

Gunawan, G., Suranti, N. M. Y., Nisrina, N., Herayanti, L., & Rahmatiah, R. (2018). The effect of virtual lab and gender toward students' creativity of physics in senior high school. *Journal of Physics: Conference Series*, *1108*, 16–43. https://doi.org/10.1088/17426596/1108/1/012043

Husnaini, S. J., & Chen, S. (2019). Effects of guided inquiry virtual and physical laboratories on conceptual understanding, inquiry performance, scientific inquiry self-efficacy, and enjoyment. *Physical Review Physics Education Research*, *15*(1), 10119. https://doi.org/10.1103/PhysRevPhysEducRes.15.010119

Kapici, hasan ozgur, Akcay, H., & Koca, ece ebrar. (2021). Comparison of the Quality of Written Scientific Arguments in Different Laboratory Environments. *International Journal of Science and Mathematics Education*, *Januari*.

Kapici, H. O., Akcay, H., & Jong, T. de. (2019). Using Hands-On and Virtual Laboratories Alone or Together ― Which Works Better for Acquiring Knowledge and Skills ? In *Journal of Science Education and Technology* (pp. 1–20). Journal of Science Education and Technology. https://doi.org/10.1007/s10956-018-9762-0

Khaerunnisak, K. (2018). Peningkatan Pemahaman Konsep Dan Motivasi Belajar Siswa Melalui Simulasi Physic Education Technology (PhET). *Jurnal Penelitian Pendidikan IPA*, *4*(2), 7–12. https://doi.org/10.29303/jppipa.v4i2.109

Kyei-Blankson, L., Ntuli, E., & Donnelly, H. (2016). Establishing the Importance of Interaction and Presence to Student Learning in Online Environments. *World Journal of Educational Research*, *3*(1), 48–65.

Lima, N., Viegas, C., & Garcia-Penalvo, F. J. (2019). Different Didactical Approaches Using a Remote Lab: Identification of Impact Factors. *Revista Iberoamericana de Tecnologias Del Aprendizaje*, *14*(3), 76–86. https://doi.org/10.1109/RITA.2019.2942256

Lowe, D., Newcombe, P., & Stumpers, B. (2013). Evaluation of the Use of Remote Laboratories for Secondary School Science Education. *Research Science Education*, *43*, 1197–1219. https://doi.org/10.1007/s11165-012-9304-3

Masril, M., Hidayati, H., & Darvina, Y. (2018). The Development of Virtual Laboratory Using ICT for Physics in Senior High School. *IOP Conference Series: Materials Science and Engineering*, *335*, 1–8. https://doi.org/10.1088/1757899X/335/1/012069

Menéndez, M. H. de, Vallejo Guevara, A., & Morales-Menendez, R. (2019). Virtual reality laboratories: a review of experiences. *International Journal on Interactive Design and Manufacturing*, *13*(3), 947–966. https://doi.org/10.1007/s12008-019-00558-7

Mirçik, Ö. K., & Saka, A. Z. (2018). Virtual laboratory applications in physics teaching. *Canadian Journal of Physics*, *96*(7), 745–750. https://doi.org/10.1139/cjp-2017-0748

Nolen, S. B., & Koretsky, M. D. (2018). Affordances of Virtual and Physical Laboratory Projects for Instructional Design: Impacts on Student Engagement. *IEEE Transactions on Education*, *61*(3), 226–233. https://doi.org/10.1109/TE.2018.2791445

Noor, Y. A., Putra, N. M. D., Nugroho, S. E., Marwoto, P., & Naini, B. (2020). Praksis Praktikum Fisika Mode Daring: Studi Kasus Pembelajaran di SMA/MA Jawa Tengah dan Jawa Timur Semasa Pandemi Covid-19. *Unnes Physics Education Journal*, *9*(3).

Panuluh, A. H., Dian Atmajati, E., & Dwi Kristanto, Y. (2020). Physics education students' perception on the use of motion detector in linear motion practicum. *Journal of Physics: Conference Series*, *1470*, 1–5. https://doi.org/10.1088/17426596/1470/1/012087

Post, L. S., Guo, P., Saab, N., & Admiraal, W. (2019). Effects of remote labs on cognitive, behavioral, and affective learning outcomes in higher education. *Computers and Education*, *140*(May), 103596. https://doi.org/10.1016/j.compedu.2019.103596

Prima, E. C., Putri, A. R., & Rustaman, N. (2018). Learning solar system using PhET simulation to improve students' understanding and motivation. *Journal of Science Learning*, *1*(2), 60–70. https://doi.org/10.17509/jsl.v1i2.10239

Puntambekar, S., Gnesdilow, D., Dornfeld Tissenbaum, C., Narayanan, N. H., & Rebello, N. S. (2020). Supporting middle school students' science talk: A comparison of physical and virtual labs. *Journal of Research in Science Teaching*, *58*(3), 392–419. https://doi.org/10.1002/tea.21664

Rowe, R. J., Koban, L., Davidoff, A. J., & Thompson, K. H. (2018). Efficacy of Online Laboratory Science Courses. *Journal of Formative Design in Learning*, *2*(1), 56–67. https://doi.org/10.1007/s41686-017-0014-0

Schröder-Turk, G. E., & Kane, D. M. (2020). How Will COVID-19 Change How We Teach

Physics, Post Pandemic? *Physical and Engineering Sciences in Medicine*, *43*(3), 731–733. https://doi.org/10.1007/s13246-020-00896-x

Steger, F., Nitsche, A., Arbesmeier, A., Brade, K. D., Schweiger, H. G., & Belski, I. (2020). Teaching Battery Basics in Laboratories: Hands-On Versus Simulated Experiments. *IEEE Transactions on Education*, *63*(3), 198–208. https://doi.org/10.1109/TE.2020.2970554

Sutarno, Setiawan, A., Kaniawati, I., & Suhandi, A. (2017). Learning Outcome dalam Pembelajaran Fisika Berbasis Virtual Lab. *Prosiding Seminar Nasional Sains Dan Enterpreneurship IV*, 194–201.

Viegas, C., Pavani, A., Lima, N., Marques, A., Pozzo, I., Dobboletta, E., Atencia, V., Barreto, D., Calliari, F., Fidalgo, A., Lima, D., Temporão, G., & Alves, G. (2018). Impact of a remote lab on teaching practices and student learning. *Computers and Education*, *126*, 201–216. https://doi.org/ 10.1016/j.compedu.2018.07.012

Wei, J., Treagust, D. F., Mocerino, M., Lucey, A. D., Zadnik, M. G., & Lindsay, E. D. (2019). Understanding interactions in face-to-face and remote undergraduate science laboratories: a literature review. *Disciplinary and Interdisciplinary Science Education Research*, *14*(1), 1–16. https://doi.org/ 10.1186/s43031-019-0015-8

Aminudin, A. H., Rusdiana, D., Samsudin, A., Hasanah, L., & Maknun, J. (2019). Measuring critical thinking skills of 11th grade students on temperature and heat. *Journal of Physics: Conference Series*, *1280*(5), 1–5. https://doi.org/10.1088/1742-6596/1280/5/052062

Anggreni, Y. D., Festiyed, & Asrizal. (2019). Meta-Analisis Pengaruh Model Pembelajaran Project Based Learning terhadap Kemampuan Berpikir Kritis Peserta Didik SMA. *Pillar of Physics Education*, *12*(4), 881–888.

Asrizal, Hendri, A., Hidayati, & Fertiyed. (2018). Penerapan Model Pembelajaran Penemuan Mengintegrasikan Laboratorium Virtual dan Hots untuk Meningkatkan Hasil Pembelajaran Siswa. *Prosidimg Semonar Nasional Hibah Program Penugasan Dosen Ke Sekolah (PDS) Universitas Negeri Padang*, *November*, 49–57.

Astalini, Kurniawan, D. A., Perdana, R., & Kurniawan, W. (2019). Identification Attitudes of Learners on Physics Subjects. *Journal of Educational Science and Technology*, *5*(1), 39–48. https://www. neliti.com/id/publications/177126/pengaruh-model-pembelajaran-dan-kesadaran-metakognitif-terhadap-hasil-belajar-pe

Bao, L., & Koenig, K. (2019). Physics education research for 21st century learning. *Disciplinary and Interdisciplinary Science Education Research*, *1*(2), 1–12. https://doi.org/10.1186/s43031-019-0007-8

Beerenwinkel, A., & Arx, matthias Von. (2017). Constructivism in Practice: an Exploratory Study of Teaching Patterns and Student Motivation in Physics Classrooms in Finland, Germany and Switzerland. *Research in Science Education*, 237–255.

Boisandi, & Darmawan, H. (2017). Meta Analisis Pengaruh Penerapan Pembelajaran Berbasis Konstruktivisme pada Materi Fisika di Kalimantan Barat. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *6*(2), 179–185.

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers and Education*, *87*(1), 218–237. https://doi.org/10.1016/j.compedu.2015.07.003

Broisin, J., Venant, R., & Vidal, P. (2017). Awareness and reflection in virtual and remote laboratories: The case of computer education. *International Journal of Technology Enhanced Learning*, *9*(2–3), 254–274. https://doi.org/10.1504/IJTEL.2017.084503

Chen, J., Wang, M., Kirschner, P. A., & Tsai, C. C. (2018). The Role of Collaboration, Computer Use, Learning Environments, and Supporting Strategies in CSCL: A Meta-Analysis. *Review of Educational Research*, *88*(6), 799–843. https://doi.org/ 10.3102/0034654318791584

Chiu, T. K. F., & Hew, T. K. F. (2018). Factors influencing peer learning and performance in MOOC asynchronous online discussion forum. *Australasian Journal of Educational Technology*, *34*(4), 16–28. https:// doi.org/10.14742/ajet.3240

Correia, A. P., Koehler, N., Thompson, A., & Phye, G. (2019). The application of PhET simulation to teach gas behavior on the submicroscopic level: secondary school students' perceptions. *Research in Science* *and Technological Education*, *37*(2), 193–217.https://doi.org/10.1080/02635143.2018.1487834

Corter, J. E., Esche, S. K., Chassapis, C., Ma, J., & Nickerson, J. V. (2011). Process and learning outcomes from remotely-operated, simulated, and hands-on student laboratories. *Computers and Education*, *57*(3), 2054–2067.https://doi.org/10.1016/j.compedu.2011.04.009

Corter, J. E., Nickerson, J. V, Esche, S. K., & Chassapis, C. (2007). Constructing Reality : A Study of Remote , Hands-On , and Simulated Laboratories. *ACM Transactions on Computer-Human Interaction*, *14*(2), 1–27.https://doi.org/10.1145/1275511.1275513

Diani, R., Latifah, S., Anggraeni, Y. M., & Fujiani, D. (2018). Physics Learning Based on Virtual Laboratory to Remediate Misconception in Fluid Material. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *3*(2), 167.https://doi.org/10.24042/tadris.v3i2.3321

Efstathiou, C., Hovardas, T., Xenofontos, N. A., Zacharia, Z. C., DeJong, T., Anjewierden, A., & Riesen, S. A. N. van. (2018). Providing guidance in virtual lab experimentation: the case of an experiment design tool. *Educational Technology Research and Development*, *66*(Februari), 767–791.

Falloon, G. (2019). Using simulations to teach young students science concepts: An Experiential Learning theoretical analysis. *Computers and Education*, *135*(March), 138–159.https://doi.org/10.1016/j.compedu.2019.03.001

Faulconer, E. K., & Gruss, A. B. (2018). A review to weigh the pros and cons of online, remote, and distance science laboratory experiences. *International Review of Research in Open and Distance Learning*, *19*(2), 155–168. https://doi.org/10.19173/irrodl.v19i2.3386

Galan, D., Heradio, R., de la Torre, L., Dormido, S., & Esquembre, F. (2017). The experiment editor: supporting inquiry-based learning with virtual labs. *European Journal of Physics*, *38*(3), 035702.

Gunawan, G., Harjono, A., Sahidu, H., & Herayanti, L. (2017). Virtual laboratory of electricity concept to improve prospective physics teachers' creativity. *Jurnal Pendidikan Fisika Indonesia*, *13*, 102.

Gunawan, G., Suranti, N. M. Y., Nisrina, N., Herayanti, L., & Rahmatiah, R. (2018). The effect of virtual lab and gender toward students' creativity of physics in senior high school. *Journal of Physics: Conference Series*, *1108*, 16–43. https://doi.org/10.1088/17426596/1108/1/012043

Husnaini, S. J., & Chen, S. (2019). Effects of guided inquiry virtual and physical laboratories on conceptual understanding, inquiry performance, scientific inquiry self-efficacy, and enjoyment. *Physical Review Physics Education Research*, *15*(1), 10119. https://doi.org/10.1103/PhysRevPhysEducRes.15.010119

Kapici, hasan ozgur, Akcay, H., & Koca, ece ebrar. (2021). Comparison of the Quality of Written Scientific Arguments in Different Laboratory Environments. *International Journal of Science and Mathematics Education*, *Januari*.

Kapici, H. O., Akcay, H., & Jong, T. de. (2019). Using Hands-On and Virtual Laboratories Alone or Together — Which Works Better for Acquiring Knowledge and Skills ? In *Journal of Science Education and Technology* (pp. 1–20). Journal of Science Education and Technology. https://doi.org/10.1007/s10956-018-9762-0

Khaerunnisak, K. (2018). Peningkatan Pemahaman Konsep Dan Motivasi Belajar Siswa Melalui Simulasi Physic Education Technology (PhET). *Jurnal Penelitian Pendidikan IPA*, *4*(2), 7–12. https://doi.org/10.29303/jppipa.v4i2.109

Kyei-Blankson, L., Ntuli, E., & Donnelly, H. (2016). Establishing the Importance of Interaction and Presence to Student Learning in Online Environments. *World Journal of Educational Research*, *3*(1), 48–65.

Lima, N., Viegas, C., & Garcia-Penalvo, F. J. (2019). Different Didactical Approaches Using a Remote Lab: Identification of Impact Factors. *Revista Iberoamericana de Tecnologias Del Aprendizaje*, *14*(3), 76–86. https://doi.org/10.1109/RITA.2019.2942256

Lowe, D., Newcombe, P., & Stumpers, B. (2013). Evaluation of the Use of Remote Laboratories for Secondary School Science Education. *Research Science Education*, *43*, 1197–1219. https://doi.org/10.1007/s11165-012-9304-3

Masril, M., Hidayati, H., & Darvina, Y. (2018). The Development of Virtual Laboratory Using ICT for Physics in Senior High School. *IOP Conference Series: Materials Science and Engineering*, *335*, 1–8. https://doi.org/

10.1088/1757899X/335/1/012069

Menéndez, M. H. de, Vallejo Guevara, A., & Morales-Menendez, R. (2019). Virtual reality laboratories: a review of experiences. *International Journal on Interactive Design and Manufacturing*, *13*(3), 947–966. https://doi.org/10.1007/s12008-019-00558-7

Mirçik, Ö. K., & Saka, A. Z. (2018). Virtual laboratory applications in physics teaching. *Canadian Journal of Physics*, *96*(7), 745–750. https://doi.org/10.1139/cjp-2017-0748

Nolen, S. B., & Koretsky, M. D. (2018). Affordances of Virtual and Physical Laboratory Projects for Instructional Design: Impacts on Student Engagement. *IEEE Transactions on Education*, *61*(3), 226–233. https://doi.org/10.1109/TE.2018.2791445

Noor, Y. A., Putra, N. M. D., Nugroho, S. E., Marwoto, P., & Naini, B. (2020). Praksis Praktikum Fisika Mode Daring: Studi Kasus Pembelajaran di SMA/MA Jawa Tengah dan Jawa Timur Semasa Pandemi Covid-19. *Unnes Physics Education Journal*, *9*(3).

Panuluh, A. H., Dian Atmajati, E., & Dwi Kristanto, Y. (2020). Physics education students' perception on the use of motion detector in linear motion practicum. *Journal of Physics: Conference Series*, *1470*, 1–5. https://doi.org/10.1088/17426596/1470/1/012087

Post, L. S., Guo, P., Saab, N., & Admiraal, W. (2019). Effects of remote labs on cognitive, behavioral, and affective learning outcomes in higher education. *Computers and Education*, *140*(May), 103596. https://doi.org/10.1016/j.compedu.2019.103596

Prima, E. C., Putri, A. R., & Rustaman, N. (2018). Learning solar system using PhET simulation to improve students' understanding and motivation. *Journal of Science Learning*, *1*(2), 60–70. https://doi.org/10.17509/jsl.v1i2.10239

Puntambekar, S., Gnesdilow, D., Dornfeld Tissenbaum, C., Narayanan, N. H., & Rebello, N. S. (2020). Supporting middle school students' science talk: A comparison of physical and virtual labs. *Journal of Research in Science Teaching*, *58*(3), 392–419. https://doi.org/10.1002/tea.21664

Rowe, R. J., Koban, L., Davidoff, A. J., & Thompson, K. H. (2018). Efficacy of Online Laboratory Science Courses. *Journal of Formative Design in Learning*, *2*(1), 56–67. https://doi.org/10.1007/s41686-017-0014-0

Schröder-Turk, G. E., & Kane, D. M. (2020). How Will COVID-19 Change How We Teach Physics, Post Pandemic? *Physical and Engineering Sciences in Medicine*, *43*(3), 731–733. https://doi.org/10.1007/s13246-020-00896-x

Steger, F., Nitsche, A., Arbesmeier, A., Brade, K. D., Schweiger, H. G., & Belski, I. (2020). Teaching Battery Basics in Laboratories: Hands-On Versus Simulated Experiments. *IEEE Transactions on Education*, *63*(3), 198–208. https://doi.org/10.1109/TE.2020.2970554

Sutarno, Setiawan, A., Kaniawati, I., & Suhandi, A. (2017). Learning Outcome dalam Pembelajaran Fisika Berbasis Virtual Lab. *Prosiding Seminar Nasional Sains Dan Enterpreneurship IV*, 194–201.

Viegas, C., Pavani, A., Lima, N., Marques, A., Pozzo, I., Dobboletta, E., Atencia, V., Barreto, D., Calliari, F., Fidalgo, A., Lima, D., Temporão, G., & Alves, G. (2018). Impact of a remote lab on teaching practices and student learning. *Computers and Education*, *126*, 201–216. https://doi.org/10.1016/j.compedu.2018.07.012

Wei, J., Treagust, D. F., Mocerino, M., Lucey, A. D., Zadnik, M. G., & Lindsay, E. D. (2019). Understanding interactions in face-to-face and remote undergraduate science laboratories: a literature review. *Disciplinary and Interdisciplinary Science Education Research*, *14*(1), 1–16. https://doi.org/10.1186/s43031-019-0015-8