Research Article

Designing Modeling-based Physics Online Learning Assisted with Home-lab-kit

Elisabeth Pratidhina[1,2], Dadan Rosana[1], Heru Kuswanto[1]

[1]Postgraduate Program, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.
[2]Department of Physics Education, Widya Mandala Surabaya Catholic University, Surabaya, Indonesia

ORCID
Dadan Rosana: https://orchid.org/0000-0003-4987-7420
Heru Kuswanto: https://orchid.org/0000-0002-2693-8078

Abstract.
Learning Physics online can lead to issues such as lack of student engagement and limited access to laboratory activities. This work aims to develop modeling-based physics online learning assisted with home-lab-kit to ease up on those problems. Home-lab-kit is an Arduino-based experimental kit delivered to students in advance before class. The learning model was designed by adapting the constructivism paradigm. We designed the learning activity and implemented it in a group of 10 college students majoring in physical education. Using a self-report checklist, we measure students' engagement before and after the learning process. There is an improvement in students' engagement with a normalized gain of 0.33, which can be classified as a medium improvement. It shows that the modeling-based physics online learning assisted with home-lab-kit is feasible in keeping the students engaded. In addition, students respond well to the learning model implementation and the supporting materials.

Keywords: modeling-based physics, online learning assisted, home-lab-kit

Corresponding Author: Elisabeth Pratidhina; email: elisa.founda@gmail.com

Published: 3 April 2024

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICMScE Conference Committee.

1. INTRODUCTION

As communication technology develops tremendously, online learning is getting popular. Online learning has several advantages, such as flexibility in the learning process [1, 2]. In online learning, students have the freedom to set up their place and time for learning. The flexibility may optimize the output of the learning process.

Despite its advantages and popularity, some study shows that online learning still faces some problems. Studies have shown that students' engagement declines during online learning [3–5]. Student engagement is a multi-facet concept that influences the quality of students' learning process [6]. In [7], students' engagement is classified student engagement into four dimensions, i.e., cognitive, behavioral, emotional, and social engagement. Cognitive engagement is related to learning strategies, self-regulation, and persistence in learning. Emotional engagement is students' emotional reactions during learning [8]. Behavioral engagement refers to students' involvement in academic activities [9]. Social engagement is related to social interactions with peers and teachers during the learning process [10]. Lack of Student engagement will become an obstacle to online learning success.

Online learning for physics subjects also faces another problem related to laboratory work. Incorporating hands-on laboratory work in online learning is difficult due to limited access to a laboratory. Laboratory work is an essential part of a physics course. It stimulates students to think critically and practice the science process. Moreover, incorporating laboratory work in physics courses can improve students' attitudes toward science [11].

In some previous studies, effective pedagogical approaches for science subjects are student-centered, active, and inquiry-based learning [12]. Those approaches have successfully improved student motivation, retention, and learning outcomes. One of the learning frameworks that adapt inquiry-based learning and constructivist paradigms is modeling-based learning [13]. Modeling is a process that scientists carry out to construct a scientific model. Modeling has been adapted to the science learning process. Students are encouraged to use the process of modeling to develop their scientific knowledge. Hestenes [14] broke the modeling process into 3 phases, i.e., modeling, model analysis, and model validation. Brew proposed five steps of modeling-based learning, i.e., introduction and representation, coordination of representation, application, abstraction and generalization, and continued incremental development [15]. Meanwhile, Wang et al. [16] introduce modeling-based learning consisting of exploration, model adduction, model formulation, and model deployment.

There is still limited study on incorporating modeling-based learning in online learning. This paper proposed a modified online learning model, which adapts modeling-based learning and incorporates hands-on practical work in the modeling process. Since access to the laboratory is difficult during online learning, we distributed a home lab kit to students. Home-lab-kit is an experimental kit that uses Arduino Uno; it is used to investigate various physics phenomena. Figure 1 illustrates the home lab kit.

In this paper, we discuss the designing process of the learning model and the preliminary test conducted. The preliminary test aims to investigate the impact of the designed learning model on students' engagement.

2. RESEARCH Method

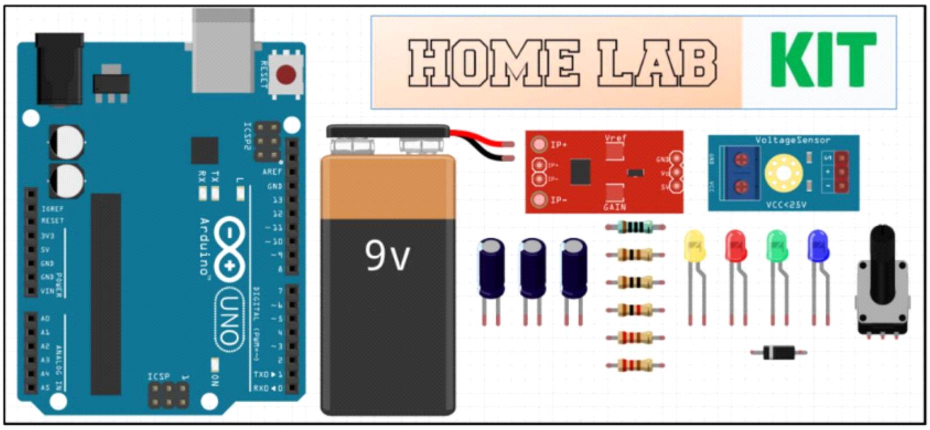

Figure 1: The component of home-lab-kit consists of arduino boards, sensors, and other electrical components.

2.1. Research Design

This study is an educational research and development, which adapt ADDIE (analysis, design, development, implementation, evaluation) model as a framework. The analysis phase consists of needs, curriculum, and task and concept analysis. In the design phase, the draft of the learning model is constructed. Supporting learning material and evaluation instruments are also designed in this phase. The development phase consists of expert appraisal and preliminary field testing. After the learning model is revised according to the expert appraisal and preliminary testing, it is implemented in several classes. This article will only explain the preliminary field testing.

2.2. Participants

Ten college students who majored in physics education participated in this preliminary field testing. These students have participated in online learning for more than a year.

2.3. Data Collecting and Analysis Technique

This research aims to determine the change in students' engagement after implementing modeling-based physics online learning assisted with home-lab-kit. The students' engagement is measured by using a questionnaire that has been developed and validated beforehand. The instruments cover the measurement of cognitive, behavioral, social, and emotional engagement aspects. The change in students' engagement is analyzed using normalized gain (*N-gain*). The *N-gain* is calculated by putting the percentage of students' engagement score before ($\%SE_{before}$) and after ($\%SE_{after}$) learning implementation to equation (1).

$$N - gain = \frac{\%SE_{after} - \%SE_{before}}{100 - \%SE_{before}} \quad (1)$$

We also investigate the students' responses to the learning model and material used. The students' response is investigated by asking students to fill out a questionnaire. The students' response from each statement in the questionnaire is converted into quantitative data, such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3, "strongly agree" = 4. The scoring data are analyzed with descriptive statistics and interpreted into categories, as in Table 1.

Table 1: Classification of the actual average score of students' responses [17].

No	Score Interval	Criteria
1	$\overline{X} > 3.4$	Very Good
2	$2.8 < \overline{X} < 3.4$	Good
3	$2.2 < \overline{X} < 2.8$	Acceptable
4	$1.6 < \overline{X} < 2.2$	Poor
5	$\overline{X} \leq 1.6$	Very Poor

3. RESULTS AND DISCUSSION

The modeling-based online physics learning activity adapts the modeling-instruction phase. The learning phase is divided into 6 stages: orientation, exploration, modeling, evaluation & revision, application, and reflection. The learning activity combines asynchronous and synchronous modes. Synchronous mode mainly uses zoom. Meanwhile, the asynchronous mode activity is primarily organized in Schoology (see Figure 2). Table 2 shows the description of each learning phase.

As a preliminary field test, we implemented modeling-based online physics learning in a group of college students at one private university in Indonesia. Ten students who majored in physics education participated in this preliminary field test. The topic discussed during the pilot test is about direct current, covering four sub-topics, i.e., Current & resistance, Series & Parallel Circuit, Kirchhoff's Rule, and Resistor-Capacitor Circuits. Before implementing modeling-based online physics learning, we delivered a home lab kit to all students participating in this study. We also introduced them to how to use the home lab kit.

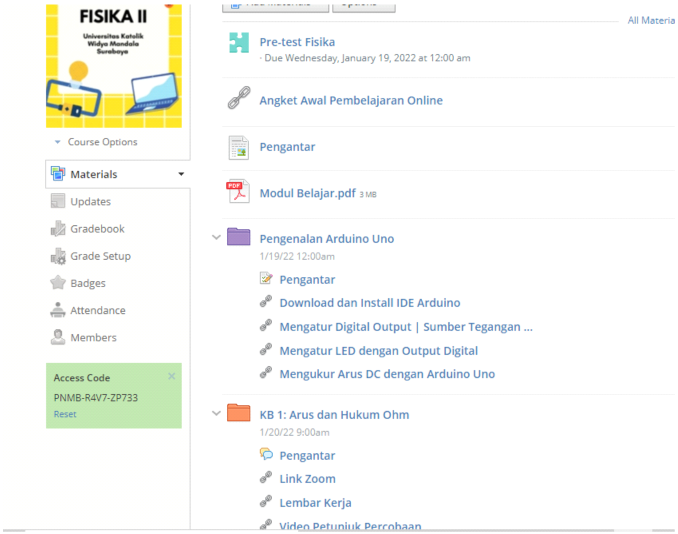

Figure 2: The learning management system.

In the preliminary field test, we wanted to know how implementing this learning model can affect students' engagement. A questionnaire to assess students' engagement has been developed before [18]. The measured students' engagement consists of four aspects: cognitive, behavioral, emotional, and social. The comparison of students' engagement before and after implementing modeling-based physics online learning can be seen in Table 3. The average percentage score of students' engagement before learning implementation is 76. Meanwhile, after learning implementation, it becomes 80.

The average percentage score of students' engagement improves from 76 to 80 after implementing modeling-based physics online learning. The normalized gain of students' engagement is 0.33, which can be categorized as a medium improvement [19]. The preliminary field testing shows that modeling-based physics online learning assisted with home-lab-kit is feasible to improve students' engagement moderately. Incorporating exploration using Arduino during online learning allows students to take part in investigating physics phenomena. Hence, students become more engaged in the learning process than when they just listen to online lectures. A previous study also reported that using Arduino for face-to-face physics laboratory courses improves students' attitudes toward learning science [20]. Modeling-based physics online learning creates constructivist environments that first stimulate students to explore and construct knowledge by themselves. Some studies have shown that constructivist learning design positively impacts students' engagement [21, 22].

After the learning model implementation, students also filled out a questionnaire asking about students' responses to the learning model, learning management system,

Table 2: The syntax of modeling-based online physics learning.

Phase	Description	Mode	Platform
Orientation	The lecturer presents a stimulus to motivate students to learn specific physics topics in the orientation phase. Students are asked to make problem statements based on the stimulus. Lecturer also explains the learning goals and the tasks for students.	Asynchronous and synchronous	Schoology, Zoom
Exploration	Students have to explore the physics phenomena through individual experiments at home. Before, a home lab kit had been delivered to all students to facilitate the experimental activity. The home lab kit is an Arduino Uno-based experiment kit. Students use the home lab kit to experiment at home. They observe, collect the data, and make documentation (see Figure 3). The role of the lecturer in the exploration phase is to monitor students' progress and offer a guide if necessary.	Asynchronous	Schoology
Modeling	Students analyze the experimental data. They are asked to model the physical phenomena using various representations, such as graphs and mathematical models. Also, they have to do a literature study related to the observed phenomena. In this phase, the lecturer or tutor is a facilitator who offers necessary consultation.	Asynchronous	Schoology
Evaluation and Revision	Students must compare the modeling result based on the experimental data to the literature in this phase. If there is a particular gap, they must find the reason and revise the model or experimental technique.	Asynchronous	Schoology
Application	Within the group, students discuss how to solve some related problems by applying the model that has been developed.	Asynchronous	Schoology
Reflection	Each group presents its modeling and application results in front of the class (see Figure 4). The lecturer leads the class discussion and gives feedback. Then, students are asked to make a reflection on the learning activity.	Synchronous	Zoom

learning module, and worksheet. The students' response is summarized in Table 4. Students gave very good responses to the learning model, learning management system, learning module, and worksheet. As also discussed in another paper [23], introducing Arduino technology to students seems to attract students' interest in learning physics. Hence, their responses are positive.

TABLE 3: Student engagement (SE) scores before and after the implementation of modeling-based physics online learning assisted with a home lab kit.

Students	**SE Score Before (%)**	**SE Score After (%)**
S1	76	83
S2	82	82
S3	47	81
S4	80	79
S5	72	92
S6	63	78
S7	80	76
S8	66	86
S9	73	76
S10	65	69
Average (%)	76	80

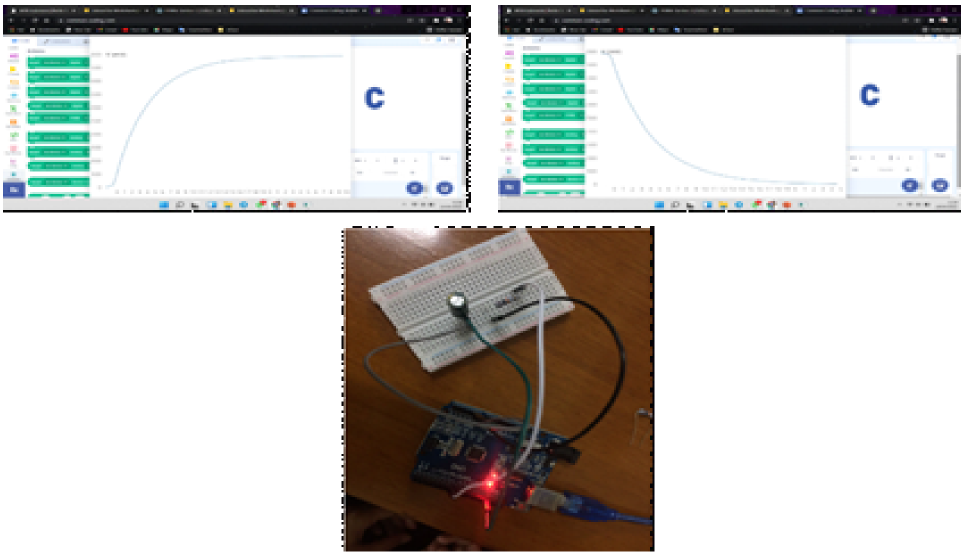

Figure 3: Home-lab-kit is used to investigate *RC* circuits by students at home .

TABLE 4: Students' response to the learning model, learning module, worksheet, and LMS.

Aspect	**Score (out of 4.0)**	**Interpretation**
Learning model	3.67	Very good
Learning module	3.66	Very good
Worksheet	3.67	Very good
Learning management system	3.60	Very good

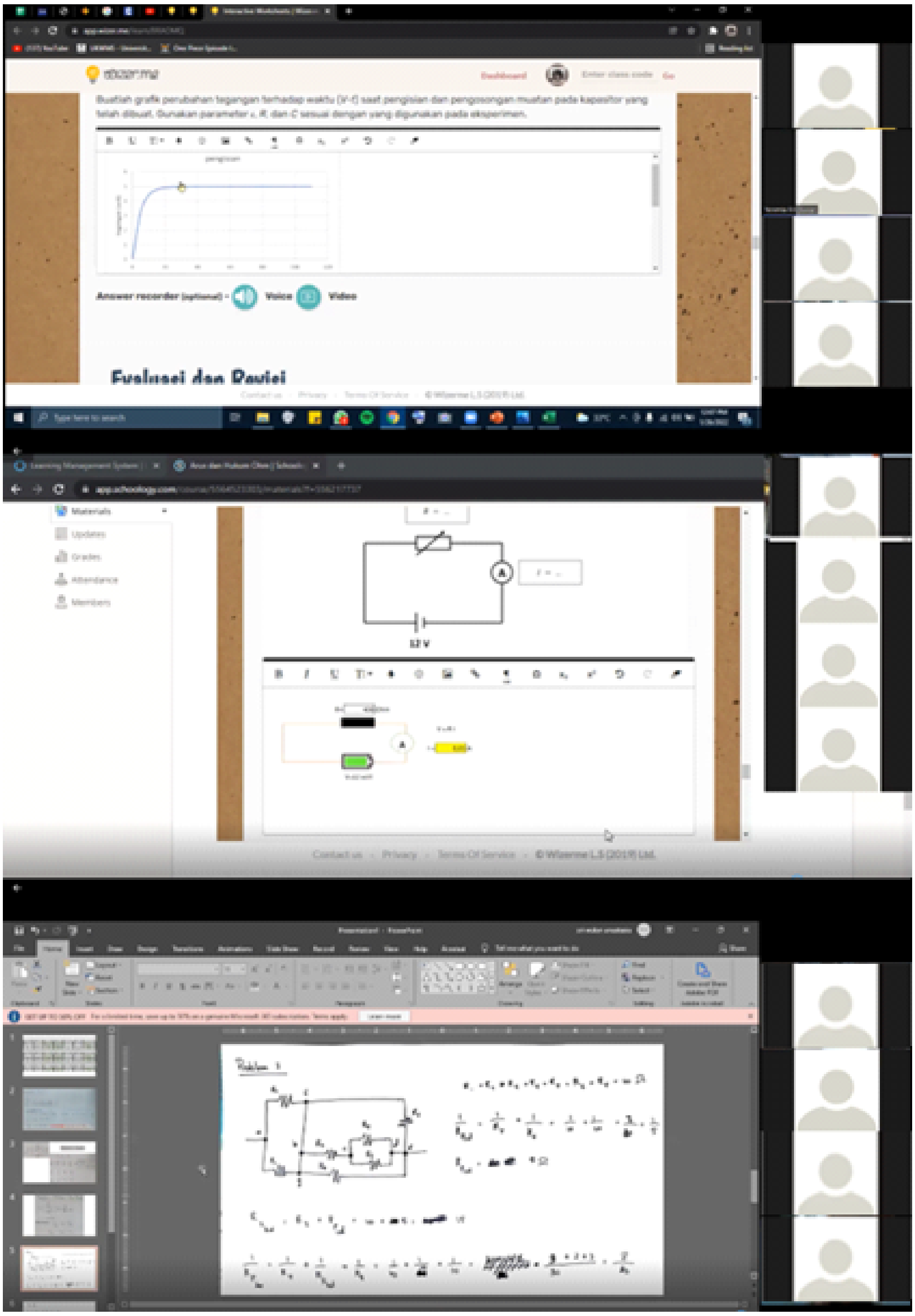

Figure 4: In the reflection phase, students present their work on modeling and application. The reflection phase is conducted through zoom.

4. CONCLUSION

Experimental activity in online learning is challenging. Utilizing Arduino Uno kit in a physics experiment may become an alternative as it is quite affordable. We have designed a modeling-based learning model with a home activity using an Arduino kit in physics online learning. Our preliminary analysis shows students' engagement in online physics learning improves moderately. This initial finding shows that using home-lab-kit and modeling-based learning in online learning is promising. Hence, in future research, we would like to widen our study to more significant participants and deepen our study to explore the impact of the learning process on improving students' competencies.

Acknowledgments

References

[1] Castro MD, Tumibay GM. A literature review: efficacy of online learning courses for higher education institution using meta-analysis. Educ Inf Technol. 2021;26(2):1367–85.

[2] Nik Md Salleh NS, Hamid R, Abdul Rahman K, Zainal Abidin IF, Zawawi AS. Learning flexibility and environmental changes with the advent of online learning during COVID-19 pandemic. Jurnal Intelek. 2022;17(1):116–27.

[3] Ștefenel D, Neagoș I. "Measuring academic engagement among university students in Romania during COVID-19 pandemic.," Thesis. vol. 9, no. 2, pp. 3–29, 2020.

[4] Bestiantono DS, Agustina PZ, Cheng TH. How students' perspectives about online learning amid the COVID-19 pandemic? Studies in Learning and Teaching. 2020;1(3):133–9.

[5] Wester ER, Walsh LL, Arango-Caro S, Callis-Duehl KL. Student engagement declines in STEM undergraduates during COVID-19–driven remote learning. J Microbiol Biol Educ. 2021 Mar;22(1):10–1128.

[6] Zhoc KC, Webster BJ, King RB, Li JC, Chung TS. Higher Education Student Engagement Scale (HESES): development and psychometric evidence. Res High Educ. 2019;60(2):219–44.

[7] Greene BA. "Measuring cognitive engagement with self-report scales: re- flections over 20 years of research.," Educational Psychologist. vol. 50, no. 14–30, p. 2015.

[8] Fredricks JA, McColskey W. The measurement of student engagement: A comparative analysis of various methods and student self-report instruments. Handbook of research on student engagement. Boston (MA): Springer US; 2012. pp. 763–82.

[9] Fredricks JA, Wang MT, Linn JS, et al. Using qualitative methods to develop a survey measure of math and science engagement. Learn Instr. 2016;43:5–15.

[10] Wang MT, Fredricks JA, Ye F, Hofkens TL, Linn JS. The math and science engagement scales: scale development, validation, and psychometric properties.

Learn Instr. 2016;43:16–26.

[11] Musasia AM, Abacha OA, Biyoyo ME. Effect of practical work in physics on girls' performance, attitude change and skills acquisition in the form two-form three secondary schools' transition in kenya. Int J Humanit Soc Sci. 2012;2(23):151–66.

[12] [12] R. Forrest, D. Pattison, J. Hawkins, M. Martens, L.T. Jacobs, and S. Chen, "A cost-effective model to address student readiness through the lens of a college physics course.," International Journal of Innovative Teaching and Learning in Higher Education (IJITLHE. vol. 2, no. 1, pp. 1–17, 2021. https://doi.org/10.4018/IJITLHE.289945.

[13] Louca LT, Zacharia ZC. Modeling-based learning in science education: cognitive, metacognitive, social, material and epistemological contributions. Educ Rev. 2012;64(4):471–92.

[14] Hestenes D. Toward a modeling theory of physics instruction. Am J Phys. 1987;55(5):440–54.

[15] Brewe E, Sawtelle V. Modelling instruction for university physics: examining the theory in practice. Eur J Phys. 2018;39(5):54001.

[16] Wang J, Jou M, Lv Y, Huang C. An investigation on teaching performances of model-based flipping classroom for physics supported by modern teaching technologies. Comput Human Behav. 2018;84:36–48.

[17] Wirjawan JV, Pratama D, Pratidhina E, Wijaya A, Untung B, Herwinarso H. Development of smartphone app as media to learn impulse-momentum topics for high school students. Int J Instr. 2020;13(3):17–30.

[18] Kuswanto H, Pratidhina E, Rosana D. Developing students' engagement in online learning questionnaire using rasch measurement model. KnE Social Sciences; 2022. pp. 225–32.

[19] Hake RR. "Interactive-engagement versus traditional methods: a six-thousand-student survey of mechanics tes data for introducting physics course am.," Journal Physics American Association of Physics Teachers. vol. 66, no. 1, pp. 64–74, 1998.

[20] Hadiati S, Kuswanto H, Rosana D, Pramuda A. The effect of laboratory work style and reasoning with Arduino to improve scientific attitude. Int J Instr. 2019;12(2):321–36.

[21] Banihashem SK, Farrokhnia M, Badali M, Noroozi O. The impacts of constructivist learning design and learning analytics on students' engagement and self-regulation. Innov Educ Teach Int. 2022;59(4):442–52.

[22] Bosman L, Chelberg K, Fernhaber S. Introduction to engineering: A constructivist-based approach to encourage engagement and promote accessibility. Global Journal of Engineering Education. 2017;19(3):237–42.

[23] Chaudry AM. Using arduino uno microcontroller to create interest in physics. Phys Teach. 2020;58(6):418–21.