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Implementing web-based e-scaffolding enhances learning (ESEL) at the center of mass conceptual understanding

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Abstract: Many online learning models are alternatives due to the Covid-19 pandemic in synchronous, asynchronous, or mixed-mode. However, resources to support independent student learning in Indonesia were still limited. The focus topic of the study is developing students' understanding of the physics concept of center of mass. A Web-based E-Scaffolding Enhance Learning (ESEL) was identified and implemented. This study used a quasi-experiment, one group, pretest-posttest design. Forty-one students participated in the research. The ESEL model involved four phases: sense-making, process management, articulation, and reflection. Students undertook ESEL-based activity developed for the online asynchronous mode implementation. In addition, synchronous meetings and sharing of learning results using an online platform. Data analysis shows that the web-based ESEL model supported online learning of the center of mass concept, though some improvements are possible. Specifically, learning outcomes increased with a significant value increase between the pre-test and post-test, and a normalized gain score of 0.73 indicated effective learning in high criteria. This research shows that the web-based ESEL approach is an effective self-directed learning tool for online physics classrooms.
Keywords: E- scaffolding, web-based, online learning.

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INTRODUCTION

The COVID-19 pandemic has impacted over 200 countries and has affected education and its operation in most countries (Hamid et al., 2020). Since March 2020, the Indonesian Government has directed that all school teaching and learning activities use distance learning to ensure social distancing and improve health outcomes. Such activities occurred both offline and online, synchronously and asynchronously. Each weekday teaching and learning process was conducted synchronously in which teachers and students 'met' using online meeting sites, such as Google Meet, for up to five hours a day. Students undertook self-directed learning on weekday afternoons, evenings, and weekends using sites such as Google Classroom. Due to COVID-19, distance education was rarely used in Indonesian schools. Both teachers and students needed to adapt to this new situation quickly.

Teachers and students needed resources and support to facilitate Learning under these new conditions. The Government promoted existing web-based learning resources for students and teaching resources for teachers. In some cases, resources had already been developed by Government agencies and by some teachers and schools. However, most of these websites consisted mainly of subject matter content or step-by-step sequences to build knowledge and understanding. There are very few Indonesian language websites with pedagogical-driven interactive learning resources connecting learning processes with the content, helping students build science understanding independently of the teacher. Furthermore, students must apply and practice scientific methods to understand the concepts being taught.

Science learning is a process and product approach to develop students' skills and understanding of the scientific principles within the activities (Yusuf & Wulan, 2016). Inquiry-based learning is one of the approaches to improving students' scientific skills and understanding and achieving deep learning. Scientific activities and skills, including observing, analyzing, predicting, and inferring, can be improved through inquiry learning (Özgelen, 2012). However, inquiry learning approaches are generally lacking in Indonesia (Sopacua et al., 2018), which is confirmed by our observations that Indonesian teachers rarely carry out remote inquiry learning. This situation may be because of a lack of equipment for experiments or few teaching resources in the Indonesian language for distance learning. Another difficulty for Indonesian teachers in facilitating inquiry learning is indirectly providing direction to students on carrying out activities.

One approach to mentoring and supporting distance learning students is using a scaffolding approach. A scaffolding approach provides introductory guidance and support, gradually reducing monitoring when students acquire more independent learning skills. In traditional face-to-face classes, teachers can give guidance directly. In distance education, a scaffolding approach using interactive website resources, such as simulations, videos, and games, can be helpful (Basu et al., 2017). Sarah (2021) concludes that using a website (a personal site) in physics learning results improves student learning outcomes. Other physics education technology, for example PhET Colorado, research shows that simulation-assisted scaffolding can improve students' critical thinking and science process skills (Dasilva et al., 2019). Another finding shows that students' scientific argumentation ability can be improved by problem-based learning (PBL) when Edu-media simulations are used (Riwayani et al., 2019). Interactive multimedia learning can effectively improve students' understanding of physics concepts (Santhalia, 2020). Mentoring with digital technologies can broaden students' insight into physics and simplify online learning. However, online learning presents some challenges, including activities for interactive questions, collaborating discussions, and issues with the availability of digital technologies and infrastructure (Nurliani, 2019).

In simple terms, scaffolding can be interpreted as temporary adaptive support or assistance to achieve independent student learning (Smit et al., 2018). Teachers develop temporary support structures for students to achieve understandings they could not achieve independently (Linder et al., 2006). Wood, Bruner, and Ross argue that scaffolding allows students to solve problems, carry out tasks or achieve specific goals (Dasilva et al., 2019). Dasilva et al. (2019) indicate that scaffolding has three levels. The first level is an environmental provision where the teacher creates a learning environment with learning resources, media, and direct encouragement and enthusiasm. The second level is explaining, reviewing, and restructuring, where the teacher interacts directly with students. Here the teacher provides opportunities for students to see, touch, and explain concepts in their own words, and then the teacher represents students' thoughts without reducing the meaning. At this level, the teacher helps students solve problems by providing examples similar to the questions. The third level is developing conceptual thinking. Here the teacher gives more abstract tasks to students to develop their conceptual thinking. Students can also develop representational tools according to the concepts studied (Dasilva et al., 2019).

Traditionally, the concept of scaffolding involves the teacher as the agent directing the scaffold implementation. However, scaffolding is applied to the development and application of learning software, with the software as the scaffolding agent supporting students' learning (Quintana & Fishman, 2006). Guzdial (1994) introduced software-realized scaffolding and explained how the concept of scaffolding could be applied to software for learning. Quintana & Fishman (2004) developed a Scaffolding Design Framework for inquiry-based science learning, presenting levels of sense-making, management process, articulation, and reflection.

In this study, a website was developed within a Google Site using Web 2.0 tools to enable collaboration between teachers and students and between students. Web 2.0 tools have many advantages, including being multi-platformed (operating system and web browser independent), applicable on mobile and desktop devices, and flexible interactivity. Web 2.0 tools are generally easy to apply and easily integrated into websites such as Google Sites, which means that most teachers can create a rich learning site. The website used in this research was purposefully designed using a scaffolding approach to present the subject matter, both the theory and investigations. Using constructivist techniques, the material connects theory and practice to build students' knowledge and scientific skills. Students can access the website using computers, laptops, or smartphones. The result is an Electronic Scaffolding Enhance Learning (ESEL) designed approach to improve online physics learning during COVID-19.

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This paper addresses implementing an ESEL-based distance education approach to teaching the Center of Mass physics concept. The flowchart of the learning plan for student interaction within the website is shown in Figure 1.

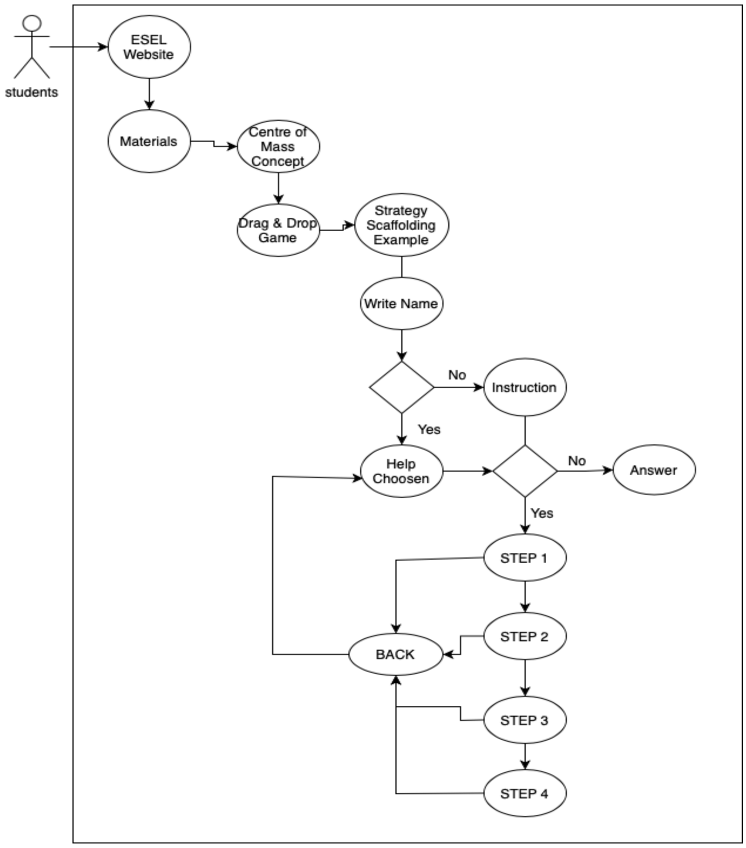

Figure 1. The Flowchart of Students' interaction

The research cohort for this study is year eleven senior high school students drawn from two Indonesian schools' physics classes. One school is a private school located in Bandung, Western Java, and the second school is a public school in Nusa Tenggara. Eleven students were from a Nusa Tenggara public school, and 27 were from a Bandung private school, being 41 students in total. Purposeful Sampling (Emmel, 2013) ensured a balance of participants from low, medium, and high ability groups. The gender balance represented the populations across the schools.

The research was conducted in a blended model of synchronous and asynchronous online learning with limited face-to-face learning. All students were grouped into one online class using Google Classroom, and each teacher from each school collaborated to become a teacher of the class. The implementation step in this study used a quasi-experimental pretest-protest method for the class as one group, as shown in Figure 2.

Phase 1	**Treatment**	**Phase 2**
Pre-test	**ESEL-based Learning**	**Post-Test**

Figure 2. Quasi-experimental one group pretest-Posttest

Before starting their learning of center of mass, students undertook a pre-test, and after their experience, they completed a post-test comprising the same questions. The test consisted of three indicators: their understanding of the center of mass of 2D homogeneous objects for the basic shape, determining the center of mass of two combined basic 2D homogeneous objects, and describing the procedure for determining the center of mass of homogeneous objects of arbitrary shape.

Implementing the ESEL approach integrated the material into a prepared Google Classroom. Students were provided with the Google Meet link for the synchronous class meetings. Following an

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initial synchronous meeting and pre-test, the Google Classroom link with instructions and links to tasks within the online classroom were provided. Tasks include an investigation that students conducted at home following the information provided. Each week, the teacher conducted an online meeting of all students using Google Meet to discuss their learning. In these meetings, students also presented and discussed their investigation reports. The implementation procedure in this research can be seen in Figure 3.

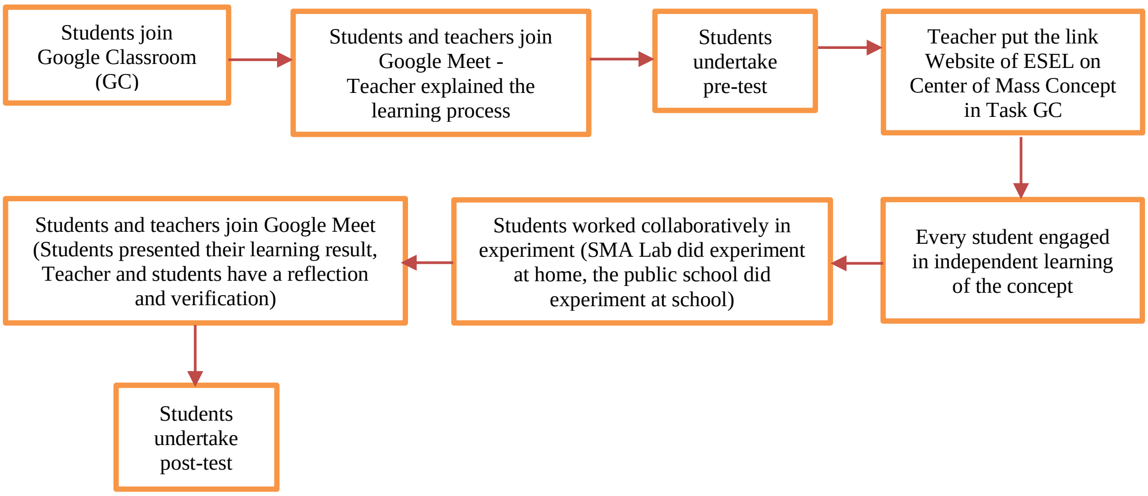

Figure 3. Procedure of Implementation

Based on the pre-test and post-test scores, the significant difference in the results of the statistically using paired t-test to identify the learning outcome and learning effectiveness was determined by identifying the normalized gain score using the following equation:

$$\langle g \rangle = \frac{T_{final} - T_{initial}}{T_{\max} - T_{initial}}$$

The normalized gain score is compared with the effectiveness criteria in Table 1 to identify learning effectiveness.

Table 1. Effectivity Criteria

Percentage	Criteria
0,70 < <g> < 1,00	High
0,30 < <g> < 0,70	Average
0,00 < <g> < 0,30	Low
<g> = 0	Stable
-1,00 < <g> < 0	Decrease

Teachers analyzed the data from every task on Google Classroom to identify students' performance and activities. Teachers determined the percentage number of students who submitted their tasks on time. Finally, to identify students' responses to ESEL, they were asked questions about their feelings and suggestions to improve the teaching approach at the end of each lesson.

RESULT AND DISCUSSION

The e-Scaffolding Enhance Learning (ESEL) approach used in this study applied the framework Quintana et al. (2004) proposed with adjustments for distance learning. There are four components of inquiry science in the learning scaffolding used. They are sense-making, process management, articulation, and reflection. In addressing improved sense-making, various representations created a bridge between prior knowledge and new knowledge we wanted students to learn. Digital tools explained the meaning of scientific concepts and symbols. Students were encouraged to use other representations to reveal the meaning of underlying data we presented or collected. In the management process, the ESEL application automatically and autonomously provided task structure and functionality from simple to complex tasks, integrated scientific skills guides, and supported routine tasks. The

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scaffolding design used to strengthen understanding of the Center of Mass Concept, in this case specifically for distance learning, consists of conceptual scaffolding, strategy scaffolding, and procedural scaffolding. Just as scaffolding can support a house in construction, here scaffolding is a support and guide to help students build their understanding. The scaffolding design of the center of mass concept can be seen in Table 2.

Table 2. Scaffolding Design on Center of Mass Concept

Purpose	Framework	Appearance of ESEL
Determine the Center of Mass of a simple 2D homogeny object (rectangle, triangle, half circle) *(Conceptual Scaffolding)*	*Sense-Making* - Students observe some objects with different coordinates of the center of mass. *Process Management* - Students explore drag and drop game - Students collect data, answer questions, and make conclusions. *Articulation and Reflection* - Students communicate the result of the data and conclusion. - Discussion, verification, and reflection through an online meeting.	- There are some 2D homogeny object - There are some equations of the center of mass coordinates. - There are three times to try matching a center of mass and the object - Verification of concept of center of the mass coordinate of the object
Determine the Center of Mass of a combined 2D homogeny object *(Strategy Scaffolding)*	*Sense-Making* Students read the question and answer when they can or select guidance *Process Management* - Students try to answer every step-by-step question - Students back to answer the question or watch the video explanation *Articulation and Reflection* Students communicate the result of the data and conclusion.	- Questions about the Center of Mass of combined objects (in this case, square and triangle on top) - There is an option whether the user wants to answer directly or follow the guidance (scaffolding answering question) - There is an articulation concept through a video explanation
Determine the Center of Mass of complex homogeny objects through experiment *(Procedural Scaffolding)*	*Sense-Making* Students read the questions about how to determine the center of mass of an irregular shape *Process Management* - Students do investigation using worksheets and guidance - Students do a project about irregular shape frame *Articulation and Reflection* - Complete a report as a result of an investigation and communicate in the reflection session	- A question about how to determine the center of mass of the irregular shape of the object - There is a worksheet on the site including guidance to determine the center of the mass and irregular shape of the object - There is a task for students to make a project of a frame with an irregular shape

In this research, ESEL tools applied to teaching a center of mass concept were achieved through an articulate storyline application as an html file. The html file application was published online at the link https://www.e-sel.belajarstem.id/materi/titik-berat. The advantage of a web-based ESEL approach is that it can be accessed by different devices, including laptops, PCs, Tablets, and smartphones, using different browsers and thus is highly accessible. Another advantage of web-based ESEL is its high responsiveness—ready to work as soon as students access it—and it can be accessed anytime, anywhere as long as students have an internet connection. Some examples of the tools can be seen in Figure 4.

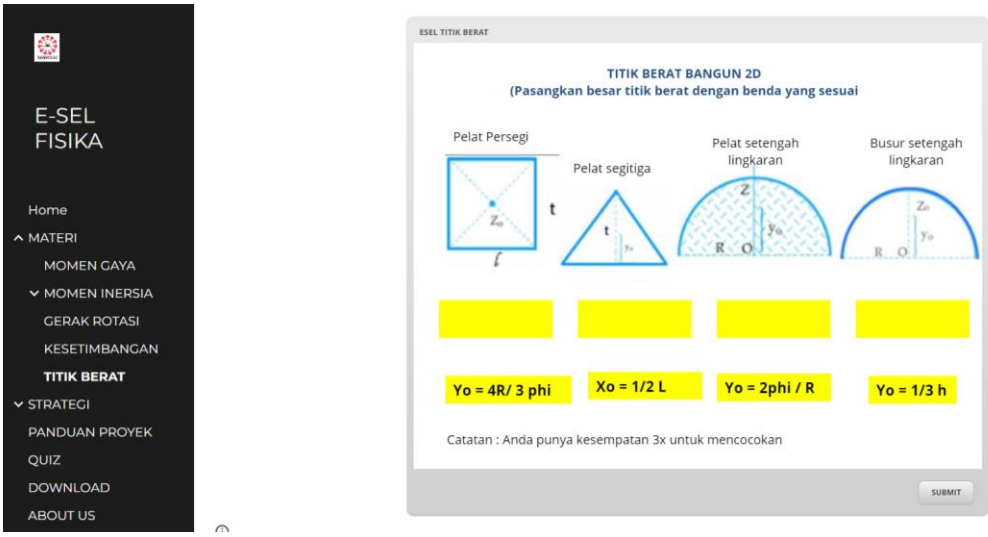

Figure 4. Conceptual Scaffolding on Center of Mass Concept

Using this ESEL-based approach, students can build their knowledge (in this research, it is about the different Centers of Mass in different shaped objects) by using a dragging and dropping tool game instead of just reading information. This process gives a dynamic learning experience that strengthens students' memory of the concept and provides students with step-by-step instructions on strategies to solve the problem. The scaffolding strategy of ESEL on the center of a mass concept is shown in Figure 5.

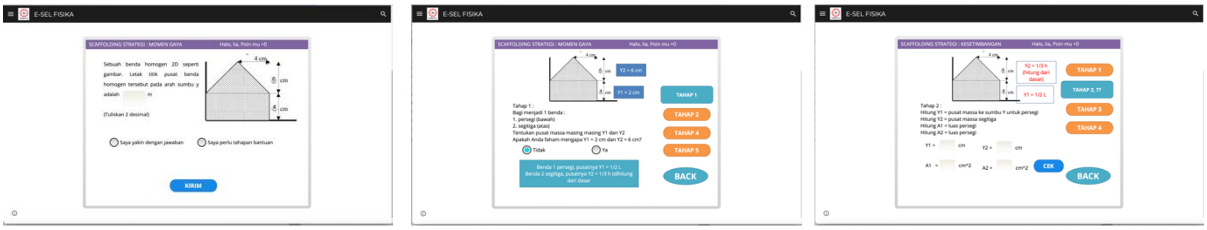

Figure 5. Strategy Scaffolding on Center on Mass Understanding

In this research, learning occurred in face-to-face, online, and mixed learning situations, synchronously and asynchronously. There were approximately two hours of synchronous, two hours of asynchronous, and two hours of face-to-face activity. The first one-hour lesson, comprising all students and teachers, occurred online through Google Meet. During this meeting, teachers explained how their asynchronous learning at home using the google classroom was to work. In this meeting, students were divided into groups. The importance of doing all the activities, such as reading materials, exploring the games, watching videos, experimenting in their group, and making presentations, was emphasized. After the first meeting, the ESEL approach was implemented in the asynchronous lessons. To guide the learning process using ESEL, teachers developed a worksheet embedded in a Google Classroom-based assignment. To undertake this activity, students needed to open the embedded link on the Google Classroom assignment. Students worked independently to complete their conceptual scaffolding in this one-hour lesson. In this lesson, students learned about the center of mass concept for various shapes of homogeneous 2D objects (basic shapes) and determined the center of mass on two basic shape combinations of homogenous 2D objects using calculation.

In the second week, teachers and students agreed to an online meeting. Students presented their learning of the topic in a discussion session. In this lesson, students from the public school presented their results in their school, and students from the private school presented their results from their home.

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This occurred because Government policy is different for each school. In this lesson, students and teachers reflected on and explained (articulation) how to determine the center of mass of two basic shape combinations of homogenous 2D objects.

In the third week, students worked in groups to investigate the irregular shape of 2D objects and their centers of mass. Students were guided by ESEL procedural design embedded in the Google Classroom assignment in this lesson. Students developed a creative project using stick frames made from ice cream sticks. Students had to make a unique stick frame and experimentally determine its center of mass. Students also developed a presentation file to present the result of the project and investigation. Students prepared their reports using web 2.0 tools such as a Google Site, Slides, Canva, or Video Collaborative. For this lesson, students from the public school conducted their experiment in their school, but students from the private school experimented at home. Every group worked collaboratively both online and faced to face. Students from the private school video showed every student working at home on the experiment.

During asynchronous learning, homeroom teachers assisted the teacher in reminding students to complete their learning assignments in the Google Classroom. For the first lesson (Conceptual Scaffolding), involving independent learning, seventeen students (41.4%) submitted their task on time, fifteen students (36.6%) were overdue, and nine students (22.0%) did not finish the task. After checking with the homeroom teachers, we found that nine students could not learn for various reasons. Some students were sick because of COVID-19, some had a personal issue such as a lack of internet connection, and some were withdrawn from school for family reasons. During the second lesson (procedural scaffolding/experiment session), Nineteen students (46.3%) submitted their task on time, and twenty-two students (53.7%) were overdue; however, 100% of students finished the task. Based on the above result, the total percentage of students who completed each stage of the learning process using ESEL on time and overdue can be seen in Table 3.

Table 3. Percentage of Students who Completed the Lesson Task

No	Lesson	Percentage of Students Completed
1	First (Conceptual Scaffolding)	78%
2	Second (Procedural Scaffolding)	100%

From this result, we can see that most students completed the first lesson tasks. All students completed the second lesson task, presenting their collaborative work and experimentation. Students demonstrated their creativity in presenting their learning outcomes by developing online video and slide presentation materials. There was no difference in learning outcome results between the public-school students who conducted their experiment in school and the private school students who conducted their experiment in their respective homes. All groups developed a final report and a video of their learning project during the experiment and successfully constructed a stick frame as their product. These results also indicate aspects of the dynamics of the students' learning experience and success because of the ESEL learning design and media used. The web-based ESEL approach to scaffold learning about the Physics concept of Center of Mass facilitated students' creativity and collaborative skills. Moreover, the results of the pre-test and post-test are summarized in Table 4.

Table 4. Average Score of Pretest – Posttest Result

No	Average of Score	Score	Standard of Deviation
1	Pre-test	40.37	10.85
2	Posttest	84.17	4.65
	Gain Score	0.73	

The calculation of significance difference using the paired t-test is 26.00, more remarkable than the t-table is 2.02 with a standard error of the difference of 1.679. This indicates a significant difference between pre-test and post-test results. Considering the standard deviation of the data, we can see that students' understanding is more homogenous in the post-test than in the pre-test score. This indicates that most students improved their understanding due to their learning. Based on this result, we can conclude that using ESEL to support learning about the center of mass concept improves students' learning outcomes.

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Additionally, the normalized gain score is 0.73, indicating that the learning effectiveness is in the high category. Therefore, it can be concluded that this web-based approach using ESEL successfully facilitated and supported self-directed learning, improving students' understanding of the Center of Mass Concept. These results align with previous research by Dasilva et al. (2019) and Ardiyati et al. (2019), which state that a scaffolding approach positively affects students' science skills and understanding of physics. Another research supporting this was conducted by Cai et al. (2021), which concluded that scaffolding in Digital Game-Based Learning could effectively improve learning outcomes.

When asked about their learning experience after it had concluded, students indicated that their learning was more attractive under the ESEL model than what they might have experienced with a traditional book or other written materials. They stated that it was easy for them to engage and understand. However, the teachers and researchers recognize that there is still the opportunity to improve the ESEL model for physics teaching. Areas for improvement are in the scaffolding strategy approach for solving complex questions and ways to improve further the application of digital technologies, including more attractive displays and animations with added sound with simulations. Further developments in digital technologies will no doubt create further opportunities for improvement.

CONCLUSION

Based on the above results and discussions, the Web-Based E-Scaffolding Enhance Learning (ESEL) approach for online learning the physics topic of the Center of Mass is successful. The research demonstrates improvement in students' learning outcomes and understanding. The success is indicated by the significant difference between pre-test and Post-test scores. The implementation results in the private and public schools show that online physics learning using Web-Based ESEL on the center of mass concept is highly effective, with a normalized score of 0.73. In addition, students demonstrate their creativity and collaborative working during the learning process. Students indicate a positive experience of their learning under the model. The research also indicates opportunities for improvement, specifically in the scaffolding strategy feature for solving complex questions. The findings of this study indicate that it is worthwhile further developing and using Web-Based ESEL as an online learning design and implementation approach and that it is a viable approach for Physics distance education. Finally, further research with such development and implementation will inform researchers and practitioners on this topic.

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