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USING E-SCAFFOLDING TO DEVELOP STUDENTS' SCIENTIFIC REASONING THROUGH INQUIRY-BASED LEARNING

S. Koes Handayanto[1], S. Fawaiz[2], A. Taufiq[3]
Universitas Negeri Malang, Malang, Indonesia.
E-mail: [1]supriyono.koeshandayanto.fmipa@um.ac.id; [2]sahalfawaiz@gmail.com; [3]ahmad.taufiq.fmipa@um.ac.id

Abstract. *Introduction.* Through inquiry-based learning (IBL), scaffolding is provided to help students develop their scientific reasoning (SR). However, the results obtained by students vary depending on their prior knowledge because the strategies of scaffolding vary on demand. Therefore, the different levels of scaffolding should be provided to all students based on their prior knowledge to facilitate their internalisation of new information in the classroom.

Aim. The present research *aimed* to examine students' SR in a course involving two electronic scaffolding levels (e-scaffolding) in IBL.

Methodology and research methods. The authors conducted a mixed-methods explanatory study followed by semi-structured interviews and think-aloud exercises with two classes (experimental and control) of 64 physics students in Indonesia for eight weeks. The authors collected the quantitative data by testing their prior knowledge and SR and obtained the qualitative data from the interviews and the think-aloud exercises, learning activities, photos, videos, and teachers' notes. ANOVA analysis of the quantitative data and thematic analysis of the qualitative data were performed.

Results and scientific novelty. To our knowledge, our research marks the first instance of providing scaffolding with a tiered level option, a feature previously limited to a single level. It was found that there were significant differences in students' SR based on students' prior knowledge of the subject. E-scaffolding developed more on SR for students with low prior knowledge. Taking notes as a habit and switching roles during experiments helped improve students' SR. It was observed that the students with low prior knowledge still needed e-scaffolding buttons to master physics concepts. Meanwhile, the students with high prior knowledge employed e-scaffolding buttons only to answer task completion.

Practical significance. Based on the research findings, the tiered e-scaffolding produced in this work opens a new potency to be applied by physics teachers to enhance student' SR. Additionally, educational technology developers may consider tiered e-scaffolding designs to provide an adaptive system.

Keywords: e-scaffolding, inquiry-based learning, scientific reasoning, prior knowledge.

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ИСПОЛЬЗОВАНИЕ ЭЛЕКТРОННОГО СКАФФОЛДИНГА ДЛЯ РАЗВИТИЯ НАУЧНОГО МЫШЛЕНИЯ СТУДЕНТОВ ЧЕРЕЗ ОБУЧЕНИЕ НА ОСНОВЕ ЗАПРОСОВ

С. Коес Хандаянто[1], С. Фаваиз[2], А. Тауфик[3]
Государственный университет Маланга, Маланг, Индонезия.
E-mail: [1]supriyono.koeshandayanto.fmipa@um.ac.id; [2]sahalfawaiz@gmail.com; [3]ahmad.taufiq.fmipa@um.ac.id

Аннотация. *Введение*. Благодаря обучению на основе запросов (IBL) скаффолдинг используется, чтобы помочь студентам развивать их научное мышление. Тем не менее результаты, полученные студентами, варьируются в зависимости от их предыдущих знаний, потому что стратегии скаффолдинга различаются исходя из запроса. Поэтому всем учащимся должны быть предоставлены различные уровни скаффолдинга на основе их предыдущих знаний, чтобы облегчить усвоение новой информации в классе.

Цель исследования – изучить научное мышление студентов на основе курса, который включает два уровня электронного скаффолдинга в обучении на основе запросов.

Методология и методы исследования. Авторы провели поисковое исследование, используя смешанные методы, а также полуструктурированные интервью и упражнения «размышляй вслух» в двух классах (экспериментальном и контрольном) среди 64 учеников 11 класса, изучающих физику в государственной средней школе в Индонезии, в течение восьми недель. Авторы собрали количественные данные, определив предварительные знания учеников и их научное мышление, и получили качественные данные из интервью и упражнений «размышляй вслух», фотографий, видео активности и заметок учителей. Провели анализ ANOVA количественных данных и тематический анализ качественных данных.

Результаты и научная новизна. Это исследование является первой попыткой предоставления скаффолдинга с многоуровневыми вариантами, и функции, которая ранее ограничивалась единственным уровнем. Было обнаружено, что существуют значительные различия в саморегуляции студентов в зависимости от предварительных знаний студентов по предмету. Электронный скаффолдинг развивается сильнее в саморегуляции для студентов с низким уровнем предварительных знаний. Обнаружено, что привычка вести заметки и менять роли во время экспериментов помогла улучшить саморегуляцию студентов. Было отмечено, что студенты с низким уровнем предварительных знаний нуждались во вспомогательных элементах скаффолдинга для овладения понятиями физики, в то время как студенты с высоким уровнем знаний использовали вспомогательные элементы скаффолдинга только для ответа на выполнение задачи.

На основе результатов исследования сделан вывод, что многоуровневый электронный скаффолдинг открывает новую возможность для использования учителями физики в целях улучшения научного мышления учащихся. Кроме того, разработчики образовательных технологий могут принять во внимание дизайн многоуровневого электронного скаффолдинга для обеспечения адаптивной системы.

Ключевые слова: электронный скаффолдинг, обучение на основе запроса, научное мышление, предварительные знания.

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USO DE LA METODOLOGÍA DE ANDAMIAJE O E-SCAFFOLDING PARA DESARROLLAR EL RAZONAMIENTO CIENTÍFICO DE LOS ESTUDIANTES A TRAVÉS DEL APRENDIZAJE BASADO EN LA INVESTIGACIÓN

S. Koes Handayanto[1], S. Fawaiz[2], A. Taufiq[3]
Universidad Negeri Malang, Malang , Indonesia.
E-mail: [1]supriyono.koeshandayanto.fmipa@um.ac.id; [2]sahalfawaiz@gmail.com; [3]ahmad.taufiq.fmipa@um.ac.id

Abstracto. *Introducción*. A través del aprendizaje basado en la investigación, en sus siglas en inglés (IBL), se utiliza la metodología de andamiaje o E-scaffolding para ayudar a los estudiantes en el desarrollo del razonamiento científico. No obstante, los resultados obtenidos por los estudiantes varían dependiendo de los conocimientos previos que hayan tenido, puesto que las estrategias de la metodología de andamiaje varían según la demanda. Es así, que a todos los estudiantes ha de proporcionarse, en función de sus conocimientos previos, diferentes tipos de andamiaje para facilitar el aprendizaje de la nueva información ofrecida en el aula.

Objetivo. El propósito del estudio es examinar el razonamiento científico de los estudiantes a través de un curso que incluye dos niveles de metodología de andamiaje o E-scaffolding en el aprendizaje basado en la investigación.

Metodología, métodos y procesos de investigación. Los autores llevaron a cabo un estudio exploratorio utilizando métodos mixtos, entrevistas semiestructuradas y ejercicios de razonamiento en voz alta en dos clases (experimental y de control) entre 64 alumnos de la clase física de 11º grado en una escuela secundaria pública de Indonesia durante un período de ocho semanas. Los autores recopilaron datos cuantitativos que midieron el conocimiento previo y el pensamiento científico de los estudiantes, y obtuvieron datos cualitativos de entrevistas y ejercicios de razonamiento en voz alta, fotografías, videos de actividades y notas de los profesores. Realizaron un análisis ANOVA de datos cuantitativos y análisis temático de datos cualitativos.

Resultados y novedad científica. El presente estudio se constituye en el primer intento de dotar a los andamios o E-scaffolding de opciones multiniveles, una función que anteriormente estaba limitada a un solo nivel. Se encontró que habían diferencias significativas en la autorregulación de los estudiantes en función de sus conocimientos previos sobre la materia. Los andamiajes o E-scaffolding desarrollan una autorregulación más fuerte para los estudiantes con conocimientos previos deficientes. Se descubrió que el hábito de tomar notas y cambiar de roles durante los experimentos ayudaba a mejorar la autorregulación de los estudiantes. Se observó también, que los estudiantes con bajos niveles de conocimientos previos requerían de elementos de ayuda de los andamiajes para dominar los conceptos de física, mientras que los estudiantes con altos conocimientos previos utilizaban estos mismos elementos de ayuda sólo para responder a la tarea.

De acuerdo a los resultados del estudio, se ha concluido que los andamiajes o E-scaffolding de varios niveles abren una nueva oportunidad para que los profesores de física los utilicen para mejorar el razonamiento científico de los estudiantes. Además, los desarrolladores de tecnología educativa pueden considerar el diseño de andamiajes multinivel para garantizar un sistema adaptable.

Palabras claves*:* andamiaje o E-scaffolding, aprendizaje basado en la investigación, razonamiento científico, conocimientos previos.

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Introduction

Scientific reasoning (SR) has been considered essential for students' future accomplishments [1], and students' SR has become one of the most popular research topics in the 21st century [2]. In addition, researchers have reported that strengthening students' SR helps them develop skills in critical thinking [3] and real-world problem-solving [4, 5]. At the same time, SR is a complex construct, and addressing and improving it requires careful planning by teachers [6].

SR is defined as processes of scientific inquiry in reconstructing theories about the world; the reasoning skills consist of experimentation, evidence evaluation, and inference-making addressed to scientific understanding. A. E. Lawson [7] divided students' SR into concrete, transitional, or formal. In studies in Indonesia, most junior high school students displayed only concrete SR, the lowest level [8, 9], and other researchers found the same results among high school students, who sometimes possessed no SR at all [10–12]. In addition, researchers have established that students who lack effective problem-solving strategies [13] or focus [14] develop only barely adequate SR if they develop it at all. Some researchers assert that SR is not a content-free process. Scientific reasoning processes grow concurrently with the development of science content [15]. On the other hand, the processes take place when applying inquiry-based learning (IBL), where hypotheses are clarified as observations are assembled and variables concretised [15].

In many previous studies, some strategies have proven effective in developing students' SR. For example, students' SR was improved by applying differentiated modules through problem-based learning [16], a model of application-oriented SR [17], active-learning methods (experimentation and discussion) [18], scientific animations [19], and modelling strategy [20]. However, M. Taub et al. [21] found that game-based technology did not necessarily improve students' SR and they concluded that the same techniques will not work for every student.

Only few research have developed students' SR utilising IBL. For example, a study by M. Novo and Z. Salvadó [22] found that students' SR is trained effectively through IBL. In addition, J. M. Kant et al. [23] demonstrated that video modeling of IBL could effectively improve students' SR. However, the two different interventions that J. M. Kant et al. implemented might not be suitable for classes of students with significant differences in knowledge levels because the students will require additional guidance.

Through IBL, students' SR develops dynamically. The development of each sub-SR is facilitated by each activity of IBL [24]. For instance, students need to utilise two main scientific reasoning strategies when designing experiments: controlling variables and combining variables. Furthermore, in the phase of testing the adequacy of the conclusion, students do correlational thinking to conclude the student results.

In contrast, one group of researchers found that IBL improved all SR components from the beginning to the middle of the intervention. However, there was no improvement at the end of the period [25]. Another skill tested did not improve making hypotheses; participants' hypotheses were rarely supported because making them required knowledge of the topic of investigation that students rarely had [25]. Students also tend to do experimentation-engineering models because they want to succeed in data reproduction [26]. These behaviours may be one factor that retards students' SR development. In an attempt to minimise retard and reduce cognitive load, many researchers suggest using scaffolding in IBL [15, 27]. Based on these findings, we argue that combining inquiry learning with technology might improve and maintain students' SR. Specifically, we propose electronic scaffolding or e-scaffolding to integrate the two levels.

The previous study provides evidence that prior knowledge is a critical element in determining students' performance [27] and IBL with e-scaffolding can improve students' SR. Therefore, this research applies IBL with e-scaffolding to know the effect on students' SR with statistically controlled students' prior knowledge. Students need to be given the option of which level of guidance to utilise since each class has just one level. In addition, the variation of the methodology in using a mixed method is bridging the gap since most research has relied only on quantitative data collection. This study aims to include qualitative data to understand better how students use e-scaffolding and the effect on SR learning process and development, which involve IBL. Specifically, our study is guided by the following two research questions:

Is there any difference in students' SR between IBL with e-scaffolding and IBL of students' high prior knowledge?

Is there any difference in students' SR between IBL with e-scaffolding and IBL of students' low prior knowledge?

How does IBL with e- scaffolding affect students' SR?

Literature Review

Developing Scientific Reasoning with Inquiry Learning

According to research in cognitive neuroscience, SR is affected by close transfer situations in the lateral pre-frontal area through instructional methods based on executive function [28]. Furthermore, it was also connected to how well the temporal lobe area performs regarding causal reasoning and hypothesis generation. This case clarifies the relationship between declarative memory processes like encoding, consolidation, and recall related to SR. Therefore, executive function and process working memory are linked to the hypothesis and experiment spaces in the scientific discovery as a dual search (SDDS) model by Klahr and Dunbar [29] as an SR development framework.

SR plays two roles in IBL. First, SR is an ability that assesses a student's competence in performing scientific tasks and encourages the acquisition of knowledge during IBL [15, 30]. Second, students practise their SR at each stage of learning through IBL [24]. For instance, during the experimental designing stage, students can exercise combinatorial and control of variables strategies [15]. Therefore, different levels of inquiry have a different impact on every aspect of SR caused by the rich experience of students from the activities [31].

Influence of Prior Knowledge on Scientific Reasoning

Three types of knowledge are necessary for SR: content knowledge, procedural knowledge, and epistemic knowledge [32]. All three types are built so the general public can understand issues, comprehend why scientists concur or differ, interact intensely with experts, and encourage practical action [33]. According to a view founded on brain activation, contextual associations between events and information retrieval from long-term memory are a way for SR to be connected to declarative memory processes [28]. It motivates a person to build explanations, directs discovery-oriented behaviour, and promotes the early development of the capacity to perform SR [34, 35], when the information from the stimulus is inconsistent with PK [29, 36], previous experience [29] or domain information [37].

Various PK levels influenced students' SR success. For instance, students with low prior knowledge (SLPK) have the propensity to create hypotheses based solely on conjecture and without using reasoning [38]. Furthermore, because there was too much information and opportunity for active participation, the SLPK was disadvantaged because of a lack of experience and knowledge in the content area [39]. However, a study by T. Brukckermann et al. [40] found that the PK level had no impact on the SR because participants needed to have the same experience alternating between known scientific activities (conducting practical work and gathering data) and unfamiliar scientific activities (planning experiments and analysing data). In-depth research can clarify this ambiguity [27].

Role of Scaffolding During Inquiry Learning on Scientific Reasoning

Guidance influenced the success of inquiry learning [39, 41]. Scaffolding is a specialised type of guidance that usually appears at various ages [42] to assist and guide students with their initial aim of enhancing the quality of their learning of physics [43] and problem-solving abilities [44]. The research by Belland B. R. et al. shows that delivering scaffolding via computer is equally effective as delivering scaffolding one-on-one [45].

According to some study findings, teachers should provide scaffolding when building SR [27, 28] because it facilitates connections between sub-SRs [30] and links between past and new phenomena [26] to reduce the cognitive load on students who receive scaffolding [46]. Although each student requires various levels of scaffolding, N. Großmann and M. Wilde [47] argued that scaffolding should not be mandated for all students. Since various students require different scaffolding simultaneously, each SR sub can be trained effectively [25]. In particular, SR and experimental design skills were developed using guided instruction in research by L. Blumer [48]. The findings show that only the least prepared undergraduate pupils had different outcomes.

We consider the various effects of scaffolding in Inquiry-Based Learning (IBL) on student SR. Furthermore, the literature review findings also indicate the impact of prior knowledge on student SR. Students with high prior knowledge do not require scaffolding. Therefore, the SR of students with low prior knowledge tends to improve after learning through IBL with scaffolding.

Methods

We conducted this mixed-methods study with a precisely sequential design in which we used the qualitative results to gain an in-depth understanding of the initial quantitative results [49]. To collect the quantitative data, we employed a post-test-only quasi-experiment to measure SR in four groups of students divided according to experimental group versus the control group and by prior knowledge level. For the qualitative data, we conducted semi-structured interviews with some participating students and gave them a seven-question think-aloud assignment to sum up their experiences.

Participants

The initial participants were 68 students in grade XI who were majoring in science at one of the public high schools in Indonesia (i.e. M_{age} = 17.03 years; *SD* = 0.31 years old), and we used random cluster sampling in two different classes to select them; most of the participants were Malay and from families with farming or merchant backgrounds. We excluded four students from the analyses because three did not participate in all the physics classes, and one was absent on the day of the SR testing; therefore, we analysed the data from the 64 students, who completed the entire intervention. There were 34 students in a class that used the e-scaffolding in IBL, and 30 students were in a class that used IBL only, and we split the students at the prior knowledge median to separate them into low (SLPK) versus high (SHPK) prior knowledge.

Data Collection

Fluid Scientific Reasoning Test

We measured the students' SR using a multiple-choice essay test on the topic of fluid that we called the fluid scientific reasoning test (FSRT). The test consisted of 26 questions with their corresponding indicators as shown in Table 1. We adapted the test from the Lawson Classroom Scientific Reasoning Test [7].

Table 1

Detailed questions for each indicator

Indicator	Item number	Maximum score
Conservational reasoning (CVR)	5, 7, 9, 10, 23	4
Proportional reasoning (PPR)	3, 11, 12, 22	4
Control of variable (CoV)	17, 18, 19, 20, 21	5
Combinatorial reasoning (CBR)	25, 26	4
Probabilistic reasoning (PBR)	14, 16, 24	3
Correlational reasoning (CRR)	2, 4, 8, 15	4
Hypothetical-deductive reasoning (HDR)	1, 6, 13	5

Fluid Prior Knowledge Test

We also gave the students a fluid prior knowledge test (FPKT) with ten 4-point multiple-choice items as follows (Cronbach's $\alpha = 0.796$): (a) mechanics (2 items), (b) density (2 items), (c) pressure (1 item), (c) continuity (2 items), (d) hydrostatic pressure (1 item), (e) Archimedes's law (1 item), and (f) capillarity (1 item). The possible item scores were: (1) nonscientific explanation or no understanding of the concept, (2) alternative conception, (3) partial understanding, or (4) sound understanding. Each group of students took this test before the intervention.

Inquiry-Based Learning and the Intervention

The two classes used the same IBL model. The control class employed paper-based worksheets, whereas the experimental class used the Moodle e-learning platform to access electronic worksheets with help buttons available. IBL consisted of the following steps or stages: (a) asking questions/formulating problems, (b) formulating hypotheses, (c) designing problem solving, (d) conducting experiments, (e) collecting and analysing data, and (f) drawing conclusions.

Experiment Condition

In the first stage of the IBL, students formulated problems based on phenomena in videos or images presented on the worksheets; then, they were supposed to develop hypotheses, experimental variables, and experimental designs. At each stage, students could click a red or a yellow help button: red gave the students instructions or prompting questions to guide them the answer, and yellow gave students a space to complete a short response; the yellow button option required less student effort to produce the answers than the red button. The next step was that the students experimented and recorded their results on the electronic worksheet; a help button was again provided to help them analyse the data to reach conclusions.

Control Condition

The control class used the same stages of IBL as the experimental group except without the e-scaffolding, including help buttons. Instead, the teacher provided paper-based worksheets to guide the students in their experiments, and the students could work in groups.

Validity and Reliability

One lecturer from the Department of Physics and one physics instructor who has over ten years of teaching experience at a high school evaluated the SR indicator items and the test of prior knowledge, the worksheets and lesson plans, the e-scaffolding and think-aloud exercise, and the semi-structured interview questions; experts provided comments on the learning stages, language, conceptual issues, and scaffolding mechanism. After three modifications, we arrived at 29 FSRT items, 16 FPKT items, 7 lesson plans with worksheets, and two levels of scaffolding. Next, we conducted a pilot test for the instruments on 32 students at other public high schools. Through expert and psychometric analysis for this pilot test, we arrived at a final version of the test that we administered to 219 students. Finally, we used Instep 3.73 to analyse the data using a one-dimensional Rasch's polytomous model and removing three items from the FSRT to meet the criteria for the fit statistics, dimensionality, and reliability [50]. The Rasch analysis results for FSRT are summarised in Table 2.

Table 2

Rasch analysis results of FSRT scores

Indicators	Note
Item reliability = 0.97; Item separation = 5.90	Very good
Person reliability = 0.70; Person separation = 1.54	Acceptable
Infit/Outfit MNSQ = 0.63 – 1.45	Fit
Dimensionality = Raw variance explained by items: Unexplained variance in first contrast = 6 : 1	Unidimensionality

Procedure

According to the Indonesian curriculum, physics is taught twice weekly for 90 minutes each class, and this study was conducted for eight weeks. In the first week, we conducted observations and interviews related to the technology and the IBL that the study involved; then we gave the students in both classes the 45-minute FPKT. Before the intervention, we registered the students in the experimental class with Moodle and provided them with an electronic manual to understand e-learning. From the second to seventh weeks, the students in the two classes received different interventions with the same teacher, where the experimental class used e-scaffolding based on the IBL model, but the control class used only the IBL model.

In both classes, the topics from the second to the fifth weeks were static fluids, including hydrostatic pressure, Pascal's law, Archimedes's principle, surface tension, capillarity, and viscosity in the form of a hands-on experiment. In the sixth and seventh weeks, the students learned about fluid dynamics. In eight weeks, all students took the 90-minute FSRT. In the last week, we interviewed and conducted think-aloud exercises with some students to learn more about their experiences with Moodle and e-learning.

Interviews and Think-Aloud Exercises

We selected the participants for the interviews and think-alouds based on their prior knowledge and SR scores. We aimed to identify the patterns they relied on in improving their SR through IBL. For the think-aloud exercise, we coded students by their initials and gave them seven quantitative questions, one for each indicator. The interviews were held in a cafe near the school on holidays for about 35–45 minutes each.

First, the third author greeted the participants, conveyed the purpose and sequence of the interviews, ensured the students' anonymity in the voice recordings, and answered their questions. Next, the interviewer (third author) asked the students to convey their experiences using e-learning and a virtual practicum for the first time; participants were also asked to express their opinions on whether the e-scaffolding had helped them learn the concepts of fluids. At the end of each interview, the interviewer gave the student a blank page with seven think-aloud questions and 14 minutes to solve them. Afterward, they encouraged them to describe their thought processes as they arrived at their answers.

Data Analysis

We analysed the quantitative data via parametric analysis. First, we tested the assumptions of the analysis, such as tests for normality and homogeneity. Second, we performed ANOVA analysis in the two classes to measure differences in students' SR. Third, the qualitative data were analysed using thematic analysis to capture the themes in the students' answers [51]. All data was feasible and approved by the ethics committee with a certificate number KEPK/035/STIKes-HPZH/III/2022.

Results

Quantitative Results

Table 3 shows that the students in the experimental class had lower FPKT scores than those in the control class, but their average FSRT scores were slightly higher than those in the control class. Before we addressed the two topics of interest – the impacts of IBL activities in groups of students with different levels of prior knowledge and what if any external factors contribute to students developing SR – we tested for the normality, homogeneity, and linearity of the students' SR and their FPKT scores. On the Kolmogorov-Smirnov normality test, the results of the two tests in both classes were normally distributed ($p > 0.05$). The Levene's F homogeneity results for both tests (i.e. FSRT and FPKT) indicated that the two datasets were homogeneous: FPKT, F (1.62) = 1.517; FSRT, F (1.62) = 0.006.

Table 3

FSRT and FPKT results

Test type	Class	n	Average	Standard deviation	Sig. normality test	Sig. homogeneity test
Fluid Prior Knowledge Test	Experimental class	34	22.94	12.61	0.200	0.223
	Control class	30	27.20	15.40	0.136	
Fluid Scientific Reasoning Test	Experimental class	34	27.93	13.17	0.200	0.940
	Control class	30	24.03	13.15	0.200	

The ANOVA results in Table 4 indicate significant differences in mean SR among the SLPK students in the two classes at $p < .050$, whereas the SHPK students' mean SR differed between the two classes but only at $p > .579$, that is, not at significance. In addition, Figure 1 shows that in both classes, the second-largest percentage of students demonstrated only concrete SR. Figure 2 shows the FSRT scores in each group for each indicator.

Table 4

ANOVA results according to students' prior knowledge

Quantitative description					ANOVA result	
Students' prior knowledge level	**Class type**	*N*	**Average SR**	**Standard deviation**	*F*	*Sig.*
Low	Experimental class	19	28.30	12.45	6.956	**0.013**
	Control class	14	17.10	11.47		
High	Experimental class	15	27.46	14.46	0.315	0.579
	Control class	16	30.10	11.66		

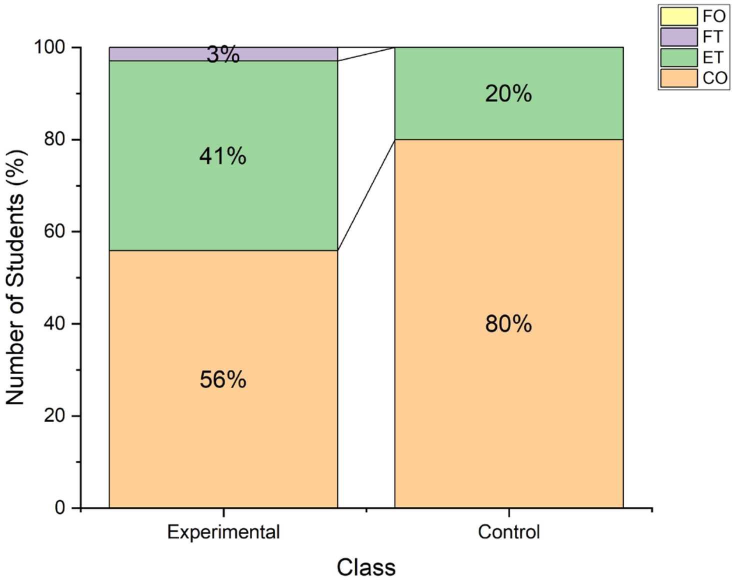

Fig. 1. Mean SR in the experimental and control classes

Notes: CO = Concrete Operational, ET = Early Transitional, FT = Final Transitional, FO = Formal Operational.

Figure 2 shows significant differences between each indicator in experimental and control classes. The experimental class had better scores than those of the control class for CRR, CVR, PBR, and COV indicators. On the other hand, the experimental class had HDR, PPR, and CBR with lower scores than those of the control class.

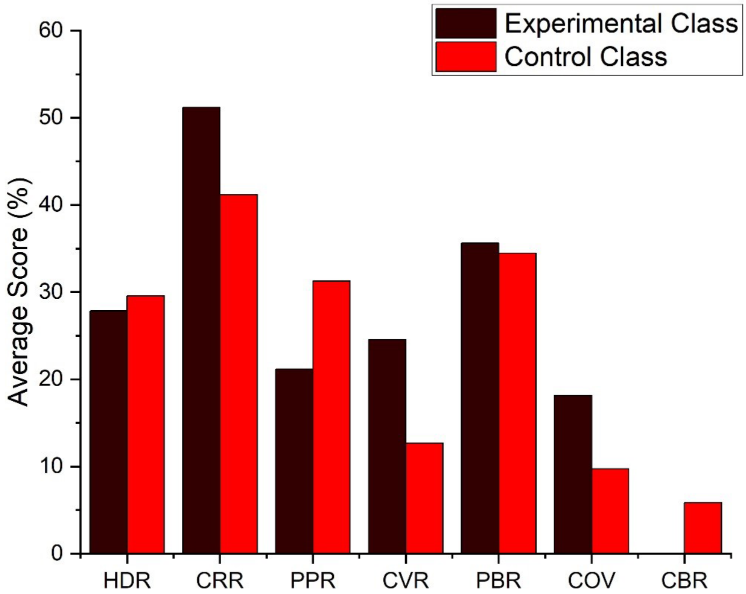

Fig. 2. SR skills in the experimental and control classes for each indicator

Notes: HDR = Hypothetical-Deductive Reasoning, CRR = Correlational Reasoning, PPR = Proportional Reasoning, CVR = Conservational Reasoning, PBR = Probabilistic Reasoning, COV = Control of Variable, CBR = Combinatorial Reasoning

Qualitative Research Results

In addition to conducting the semi-structured interviews, we gathered qualitative data through pictures and videos of the lessons, teacher notes, and semi-structured interviews. We analysed the data using NVivo 12 Plus for six students who showed strong effects of the experimental class intervention; four SLPK, and two SHPK. We identified the following themes from their qualitative data: (a) emotional engagement; (b) interaction with e-scaffolding; and (c) selection pattern of guidance level.

Emotional Engagement	SLPK	SHPK
Enthusiastic	27	14
Fun	8	1
Curiosity	2	-
Motivated	3	3

Students' Behaviour	SLPK	SHPK
Changing Role	6	-
Note-Taking	18	-
Peer scaffolding	1	2
Passive during experiment	-	10

Interaction with e-scaffolding	SLPK	SHPK
Easy to Access	3	1
Flexible	2	-
Complicated	2	4
Coherent	7	3

Selection pattern for guidance levels	SLPK	SHPK
Utilize the red button sparingly	1	-
Ignore the red button's guidance and often utilize the yellow one	-	2
Employ a balanced combination of red and yellow buttons	3	-

Fig. 3. Themes from the qualitative data

Emotional Engagement

Most students were enthusiastic about using the e-learning website and thought it was fun because it was their first experience. CHD (SLPK) showed significant enthusiasm when conducting the virtual experiments. Through IBL, the students remained interested in following their work through until they could validate or reject their hypotheses.

Interaction with E-Scaffolding

E-learning can be a more straightforward method for students to learn physics because the platforms are asynchronous and flexible, meaning they are available at any time, and the materials are attractive and easily accessible. In addition, e-scaffolding can facilitate students' IBL by guiding them through experiments in a coherent way.

Student Behaviours

SLPK and SHPK did not significantly differ in either class. SHPK were more active learners, but they often answered teacher questions out of context and were passive during the experiment. SLPK were also active learners in class but especially active during experiments. For example, MJ tended to change roles or even play multiple roles in each experiment. We also observed three SLPK (CHD, MNA, and MJ) who took notes more frequently than SHPK. We argue that the students formed this habit from both the e-scaffolding and the experiments.

Selection Pattern of Guidance Levels

We identified three patterns of students using e-scaffolding based on the help buttons they pushed during the lessons. Figure 4 graphically describes the different button functions.

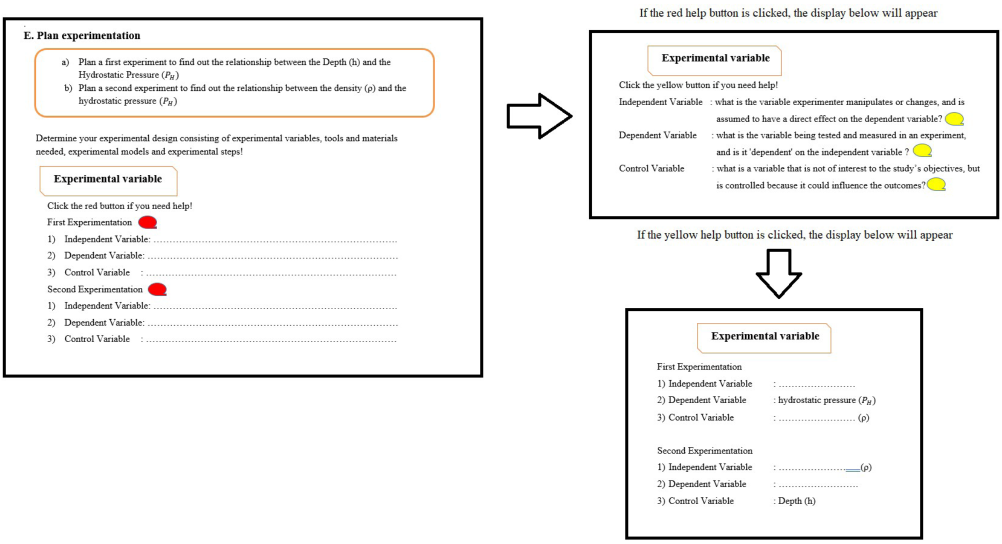

Fig. 4. The students' e-scaffolding help button options

The first pattern was instrumental help seeking, and three SLPK (MJ, CHD, FR) demonstrated this pattern, for instance:

"I have clicked all of the buttons, both red and yellow. The choice of using help buttons is based on our preferences. When I am feeling lazy, I will choose a yellow button. However, if I felt doubt, so I clicked a red button. These days, I never clicked the help button. All the buttons in the e-scaffolding are beneficial in helping me as the user".

The second pattern was independent help avoidance, requiring the red help button most or all of the time. Again, we expected many independent help seekers, but we identified only one, MNA (SLPK):

"I have only ever clicked a red button. I avoided clicking the other buttons. Even though I felt confused, I would like only focus on the red button. I hardly ever used a yellow button".

The last pattern we identified was executive help seeking, and we found two executive help seekers among the SHPK, DDS, and DB. These students preferred the yellow button because they thought it offered easier access to help; for instance, DB offered:

"I take more than half of the opportunities to use the help button. I use the yellow button more than the red button because it is easier to answer questions. I have also always used the help button in every practicum. With these buttons, I am motivated to answer questions".

Discussion

The results indicate significant differences in mean SR among the SLPK students in the two classes, whereas the SHPK students' mean SR differed between the two classes, that is, not at significance. Earlier researchers found that scaffolding provides the most benefits for SLPK [52, 53], although it does help SHPK increase their knowledge and skills [54–56]. In short, these results combined with ours indicate that students' characteristics, learning models, and the type of scaffolding affect their knowledge, skills, and SR.

There were more students in the experimental class than in the control class whose SR level increased from concrete to ET and FT, indicating potentially an effect of the e-scaffolding, but this was not the case for most of the students. Interestingly, however, the effects of scaffolding differ depending on students' prior knowledge [56, 57]; in particular, we found that SHPK were passive during the experiments, but SLPK were active in the experiments. This finding confirmed the research results from S. van Riesen et al. [53] that providing scaffolds helped SLPK use control-of-variables reasoning to understand Archimedes's concept.

SHPK should spend some time arranging their learning and/or assisting SLPK [58]; we contend that this would be very helpful for SLPK to develop their SR. According to L. Vygotsky's tenet, interactions between teachers and students, SLPK and SHPK, and students and technology demonstrate that effective learning is mediated by more sophisticated people and technologies that allow students to experience what they need to learn directly [59]. Through dialogue between them, these activities can reduce reading/writing activities, simplify complex scientific processes [22], and offer recognition in the inquiry community [15]. Additionally, the e-scaffolding supported students' reversing roles during the experiments, which instilled optimism in one of the students.

Indeed, SHPK already employ effective learning approaches to SR, and e-scaffolding hinders their processes [60]; theirs is a learning method incompatible with lengthy interactive guiding activities [61], and offering help could reduce their interest or make them doubt their current work. Previously, C. Y. Chou et al. [62] showed that SHPK could quantify their help requirements, which our findings contradict. In our research findings, SHPK often utilised executive help seeking to compare SHPK responses with those obtained from online support directly. In this study, SHPK extensively used e-scaffolding buttons only to answer task completion. This finding also explains why the learning interaction diminishes, why note-taking habits are lacking, and why expertise reversal effects arise.

Through IBL, students discover new things based on their experiences. It is crucial to record their findings, such as taking notes [63, 64] or writing in diaries a diary [65] to help people reflect on and understand incoherent situations [66] and learn from experience [67]; reflections also improve the quality of learning and knowledge construction [68]. The IBL activities are describing, justifying activities, and evaluating the concept [69]. G. Trevors also found positive effects of note taking on students' SR [70], and others found that note takers tend to have good problem-solving and self-explanation skills [71], which are both important for scientific reasoning [34, 72].

The quality of notes in IBL affects students' SR levels [64, 73], specifically in experimental contexts. Students with note-taking habits give stressing explicitly on theory and evidence as SR view [64]. D. Kuhn and E. Phelps [74] explained that recording each experimental result trains students in causal reasoning and COV. Students systematically conclude causal patterns of events based on their notes.

IBL trains students in the scientific method and ensures that they remain involved in constructing their knowledge [75], and e-scaffolding helps with that process. Students continuously practise skills, concepts, and laboratory processes [76] and learn to play different roles [24], such as proposing hypotheses, designing and conducting experiments, or statistically controlling for variables. Making decisions when the data are collected uses proportional and probabilistic skills, and concluding can improve hypothetical-deductive reasoning. Meanwhile, checking conclusions might improve student correlational skills. The IBL is an effective pedagogical approach where students can develop knowledge and thinking skills [77].

We acknowledge that our study has some limitations. The first limitation was the small sample size for the interviews, and the second was the availability of technology to access e-learning. We provided free hotspot Wi-Fi for students who needed it and lent students cell phones, although we discovered that some students were sharing one phone, which made for ineffective learning. We propose that future researchers address these limitations, for instance, by customising scaffolding to each student's prior knowledge and employing alternative instructional models and materials. For example, researchers could use a rubric to assess SR [78], or a different SR instrument might be more relevant, such as that developed by T. Abate et al. [79]. Second, a study is needed that includes gradually reducing the scaffolding based on the students' activity logs. Finally, it is necessary to incorporate reflection activities into learning. It would be interesting to recognise the effects of reflection on SR depending on students' prior knowledge following M. I. Runnel et al.'s model [69], especially using mobile note-taking software [80].

Conclusion

This research contributes to the literature on implementing e-scaffolding in IBL-based learning based on students' prior knowledge. SR skills differed according to students' prior knowledge: students with low prior knowledge demonstrated higher SR skills. E-scaffolding in IBL can promote students' SR skills, and the process is benefited by supplementation with reflection activities such as taking notes and from having students practise various roles in the experimental process.

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Information about the authors:

Supriyono Koes Handayanto – Senior Lecturer, Associate Professor, Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang; ORCID 0000-0002-5603-7473; Malang, Indonesia. E-mail: supriyono.koeshandayanto.fmipa@um.ac.id

Sahal Fawaiz – Graduate Student, Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang; ORCID 0000-0002-8680-5891; Malang, Indonesia. E-mail: sahalfawaiz@gmail.com

Ahmad Taufiq – Professor, Head of the Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang; ORCID 0000-0002-0155-6495; Malang, Indonesia. E-mail: ahmad.taufiq.fmipa@um.ac.id

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The authors have read and approved the final manuscript.

Информация об авторах:

Коэс Хандаянто Суприоно – старший преподаватель кафедры физики факультета математики и естественных наук Государственного университета Маланга; ORCID 0000-0002-5603-7473; Маланг, Индонезия. E-mail: supriyono.koeshandayanto.fmipa@um.ac.id

Фаваиз Сахал – аспирант кафедры физики факультета математики и естественных наук Государственного университета Маланга; ORCID 0000-0002-8680-5891; Маланг, Индонезия. E-mail: sahalfawaiz@gmail.com

Тауфик Ахмад – профессор, заведующий кафедрой физики факультета математики и естественных наук Государственного университета Маланга; ORCID 0000-0002-0155-6495; Маланг, Индонезия. E-mail: ahmad.taufiq.fmipa@um.ac.id

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Información sobre los autores:

Supriyono Koes Handayanto: Profesor Titular, Departamento de Física, Facultad de Matemáticas y Ciencias Naturales, Universidad Negeri Malang; ORCID 0000-0002-5603-7473; Malang, Indonesia. Correo electrónico: supriyono.koeshandayanto.fmipa@um.ac.id

Sahal Fawaiz: Estudiante de Aspirantura, Departamento de Física, Facultad de Matemáticas y Ciencias Naturales, Universidad Negeri Malang; ORCID 0000-0002-8680-5891; Malang, Indonesia. Correo electrónico: sahalfawaiz@gmail.com

Ahmad Taufiq: Profesor, Jefe del Departamento de Física, Facultad de Matemáticas y Ciencias Naturales, Universidad Negeri Malang; ORCID 0000-0002-0155-6495; Malang, Indonesia. Correo electrónico: ahmad.taufiq.fmipa@um.ac.id

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