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PAPER

The Effectiveness of an Online Inquiry-Based Learning Environment towards Secondary School Students' Behavioral Engagement and Performance in Science

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ABSTRACT

The purpose of the current study is to examine the effectiveness of an online inquiry-based learning (IBL) environment on secondary school students' behavioral engagement and performance in science. In this quasi-experimental design, 90 second year secondary school students from two classes in the Shandong Province region of China were recruited as participants. To gather the data, an online behavioral engagement questionnaire investigation and pre- and post-performance tests were administered to the experimental group (EG) and control group (CG) students. This study result shows that online IBL has a significant impact on secondary school students' behavioral engagement and performance in science subjects.

KEYWORDS

online inquiry-based learning (IBL) environment, behavioral engagement, learning performance, science

1 INTRODUCTION

The rapid development of information and communication technologies and networks has led to an explosion of online education, making it the mainstream of education. The development of online learning brings more opportunities and benefits for students' science studies. However, researchers in related studies have found that students' engagement in science has declined, with many students showing disengaged in this subject [1–5]. As the focus on science continues to gain attention, there is a growing need to address the challenges faced by students engaged in science learning, particularly in the online context [6].

Science education has become a national priority in China, and in 2023, President Xi advocated comprehensively improving the quality and effectiveness of science education at primary and secondary schools. In the past few years, most researchers

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have paid significant attention to the impact of other learning engagement (cognitive and affective) on learning science [7, 8]. In fact, behavioral engagement also plays a key role in the process of learning science. The enhancement of behavioral engagement is a useful point of entry for dropout prevention in online learning [9, 10]. As highlighted by Watkins and Mazur (2013), student engagement has been shown to be a factor in student retention in the science fields [11]. These mean that observing students' engagement in behavior is important to identify students at risk of dropping out of online science learning.

Based on the discussions above, there is a need to have a pedagogical strategy for students who are taking science. One of the suitable learning approaches is inquiry-based learning (IBL). IBL is a student-centered constructivist pedagogical strategy that guides students to actively explore problem situations to achieve inductive deduction and knowledge construction. Since people are now transitioning to online learning, the design should be appropriate for use in an online learning environment. Recently, numerous studies have revealed that inquiry-based instruction strategy, which is applied in online learning, has many potential benefits to the engagement of students [12–14]. According to Goodey and Talgar (2016), IBL motivated students to engage in learning and significantly improved their learning performance [15]. Despite the potential of IBL as a learning strategy for enhancing students' engagement, however, there are a lack of studies that look into students' behavioral engagement, especially in learning science subjects.

Therefore, this study investigates students' behavioral engagement through IBL in the science classroom. Since the amount of student behavioral engagement online is an important factor influencing student performance, this study will also investigate the effect of IBL on students' performance. This is aligned with the studies of Ma and Luo (2022), Wang (2017), and Zhu et al. (2023), which found that behavioral engagement positively impacts academic performance [16–18].

2 LITERATURE REVIEW

2.1 Online inquiry-based learning pedagogy

Inquiry-based learning is a kind of constructivist pedagogical strategy that guides students to actively explore problem situations to achieve inductive deduction and knowledge construction [19–22]. The idea of inquiry has a long history in the public school system, especially in the teaching of science, and is traceable back to educational theorists such as Dewey, Bruner, Postman and Weingarten. Inquiry reflects Dewey's belief that students need to develop critical thinking rather than memorization skills. IBL includes three types, including structured inquiry, guided inquiry, and open inquiry, depending on the degree of teacher and student leadership and the openness of the curriculum [23].

Over the past few years, numerous research results have provided evidence that IBL significantly affects students' academic performance, scientific literacy, the development of critical thinking, and the abilities of question solving (e.g., Abdi, 2014; Duran & Dökme, 2016; Onyema et al., 2019; Wale & Bishaw, 2020) [24–27]. However, although the IBL has proven effective in traditional educational settings, its adaptation for online environments as a means to complement or enhance traditional teaching remains a significant hurdle for educators. Some studies found that it is difficult for instructors to apply the same pedagogical strategies and learning activities that they develop in a face-to-face classroom to online education, especially in STEM, those practice-oriented disciplines, due to the more required hands-on activities, live demonstrations, and must-have equipment in those courses [28], and [29]. Therefore, it is important to design IBL in an online learning environment to improve students' learning.

The advances of information and the internet have facilitated the use of education technology in science education and increased the chances of successful application of IBL to online practice [30]. The combination of technology and inquiry-based instruction has great potential to facilitate student knowledge-building [31]. Online inquiry-based instructional design by researchers through technological means or in combination with modern technological devices, such as cloud labs, virtual labs, and augmented reality, is an important aspect of research in fields such as physical sciences. For example, Zahid Hossain et al. (2017) used cloud lab technology tools to integrate various stages of IBL in their study, thus making IBL more authentic, and the research results demonstrated that such cloud technology tools can support true large-scale scientific IBL [32]. Chou et al. (2022) constructed a skeuomorphic physics IBL environment with simulations designed to mimic hands-on experiments and examined whether a skeuomorphic physics IBL environment including simulation can better maximize students' understanding of scientific concepts and the scientific inquiry process compared with a similar environment without simulation. The results indicated that the group that received IBL with simulation significantly outperformed the group without simulation on the physics concept-dependent inquiry test [33]. Siantuba et al. (2023) developed and evaluated an online module based on inquiry learning with digital laboratories that was intended to address students' misconceptions in a science domain. The results of this study found that the online module based on inquiry learning with digital laboratories is beneficial to addressing misconceptions about students' performance [34].

Based on these previous studies related to IBL, this research will design an IBL online learning environment and examine its effectiveness for students' science learning. Furthermore, the IBL model proposed by Levy et al. (2015) will be chosen for instructional design in the current study, because it is considered to be suitable for science course design in an online learning environment. This IBL model follows these processes: establish a question or problem; decide on a direction or method for inquiry; explore or collect data or evidence; conceptualize, analyze, synthesize, or reflect on the problem and solution; communicate and share results [35].

2.2 Behavioral engagement in online science learning

There are researchers in related studies who found that students' engagement in science declined, many students are found to be disengaged in this subject [36–40]. Students' engagement in behavior is essential for science learning. The enhancement of behavioral engagement is a useful point of entry for dropout prevention in online science learning [41]. Watkins & Mazur (2013) indicated that student engagement has been shown to be a factor in student retention in the science fields [42]. However, in the past few years, learning science has mostly been seen as a cognitive-rational process where learners construct new concepts or restructure their existing intuitive conceptions. This leads to most researchers paying more attention to the impact of learning engagement (cognitive and affective) on learning science (Maguire et al., 2017; Dubovi & Tabak, 2021) [43] and [44]. There are few studies on student behavioral engagement in online science learning. Therefore, this study will research students' behavioral engagement in online science learning.

Behavioral engagement is an important component of the construct of learning engagement [45–48]. Behavioral engagement refers to the quantity and quality of students' observable outward behaviors or actual interactions, including time devoted to the task, effort, particication, and persistence [49–52]. In this study, online behavioral engagement is defined as the quantity and quality of engagement in behavior, including following course procedures, participation, ontask behavior (completion and time), persistence, concentration, and self-regulation.

2.3 The effectiveness of online inquiry-based learning towards students' behavioral engagement and performance

Inquiry-based learning is considered to be an approach that promote students participation and makes students active participants in the learning process. And several studies have shown that embedding inquiry-based pedagogy in online learning contributes positively to promoting active learning and improving students' behavioral engagement and performance [53] and [54]. For example, Yen-Ruey et al. (2018) investigated the engagement of male and female students in secondary science learning after engaging in inquiry-based instruction, including cognitive engagement, behavioral engagement, and affective engagement [55]. The findings found that overall, males benefited more than females from the intervention in terms of motivation and engagement in learning science. Styliani (2019) explored student engagement in inquiry learning, focusing on the structure of student engagement in relation to IBL stages in an attempt to identify the types of engagement prevalent at each stage of IBL [56]. According to the results of the study, all high-achieving students were highly engaged, and there was an increase in student behavioral engagement. Highly engaged, low-achieving students showed strong behavioral engagement, and low-achieving students showed low behavioral engagement in terms of high engagement.

Although the above studies illustrate the positive effects of applying IBL in online learning environments to promote student behavioral engagement and performance, most of these studies were not conducted in science subjects. Hence, this research aimed at exploring the effects of IBL on students' behavioral engagement and performance in online science subject learning.

3 METHOD

3.1 Research design

This research used both a pre-test and a post-test quasi-experimental design. This quasi-experimental study will be conducted in two different classes (A and B) at the same educational level. One class is assigned as an experimental group (EG), and the other is assigned as a control group (CG). In the EG, students will study science knowledge in an online IBL environment designed by instructors. While in the CG, students will study online without any design. After the intervention, both groups will conduct a pre- and post-tests in order to determine the effect of this experiment. Each group was given the same time during the treatment.

3.2 Participants

There are 90 second year students of a public secondary school in the Shandong Province region who were enrolled in the Science Subject course during the first semester of the 2023–2024 academic year and participated in the study. Students from class A were designated as the EG (n = 45), while students from class B were designated as the CG (n = 45). Science is the necessary course in the second year of public secondary school, and the students are asked to learn knowledge about light phenomena.

3.3 Instruments

Online behavioral engagement questionnaire. To measure students behavioral engagement in online science learning, the researcher selected an online behavioral engagement questionnaire developed by Abbasi et al. (2023) to measure in this study. Then, the researcher made some modifications based on the context of China, for example, the language. After modification, this instrument consisted of 17 items on a 5-point Likert scale, ranging from never (rated 1) to always (rated 5). The reliability value of the test measured by Cronbach's alpha was found to be 0.881, indicating good reliability.

Performance test. In order to measure students' scientific knowledge about light phenomena, the researchers designed performance tests and gave control and EGs at the beginning of the formal lesson and the end of online science learning. This test was created to represent the final examination questions in the science subject course, which includes 10 questions with a maximum total score of 30 marks for the practical assessment.

Online Inquiry-based science learning in an EG. The researcher designed the Online IBL science learning module through NOBOOK (https://www.nobook.com/) and the Go-Lab platform (https://www.golabz.eu/). NOBOOK virtual simulation experiment software is a series of products specifically developed for interactive teaching and student experimental exploration in primary and secondary schools. It provides virtual simulation experiments that are authentic, interactive, and innovative, catering to the diverse needs of students across different subjects (e.g., physics, chemistry, biology, etc.) and grade levels (for example, primary school, middle school, and high school). Go-Lab is an online learning platform where students can engage in IBL in a structured and supportive way [57]. One of the basic inquiry phases was used to shape the overall structure of this module [58], which includes five phases: establish a question or problem, decide on a direction or method for inquiry, explore or collect data or evidence, analyze the problem and solution, communicate, and share the result. This Online IBL science module is shown in Figure 1, and the five phases of IBL can be seen on the left-hand side.

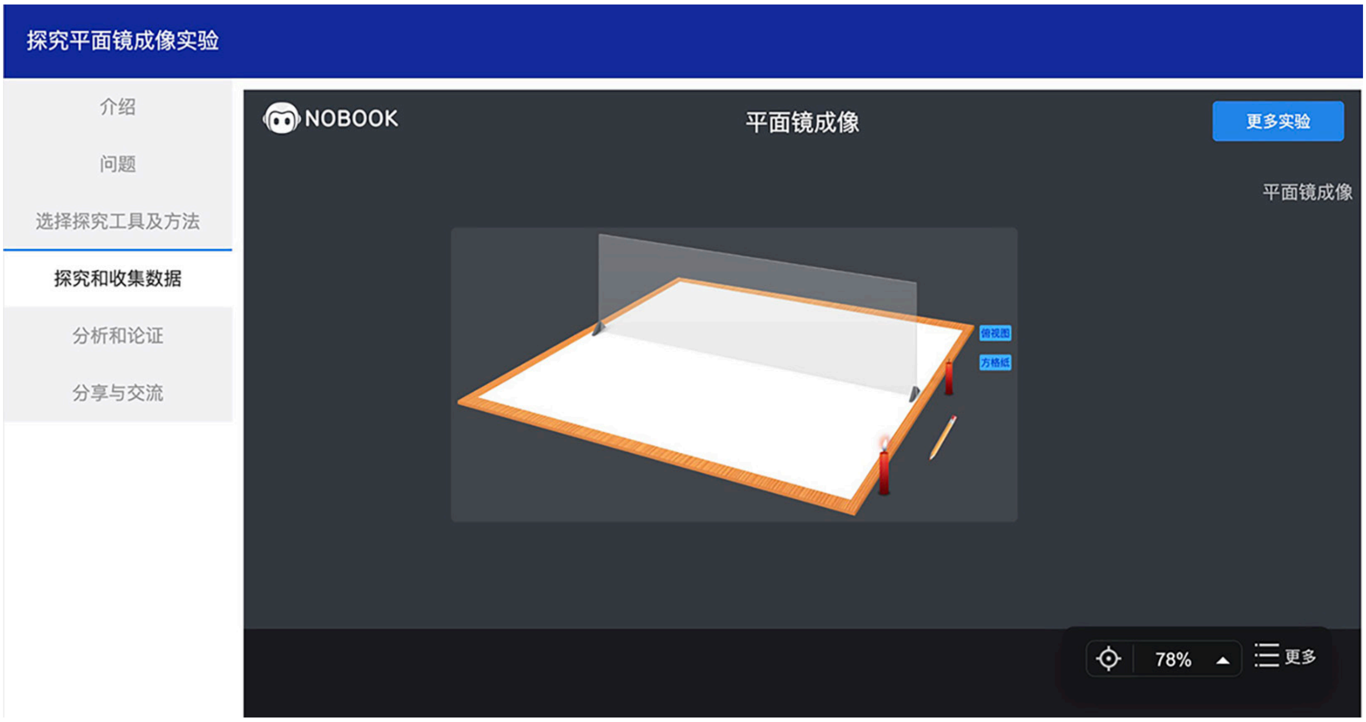

Fig. 1. Phases of an IBL showing the explore or collect data or evidence phase with a NOBOOK simulation

Online science learning in CG. In this group, the teacher explained the topic of light phenomena to be studied using PowerPoint slides in an online learning environment. The teacher instructed scientific knowledge by giving examples of light topics related to their culture and daily lives and watching science experiment videos related to light phenomena.

3.4 Procedures

Firstly, pre-performance was given to students in the EG and CG before teaching the formal lesson. Then, students of both groups were taught four lecture hours, which were a series of online science lessons on the study of light phenomena. Students in the EG were taught four lecture hours in an inquiry-based online science learning environment. Meanwhile, students in the CG studied these courses in a non-inquiry-based online science learning environment. After four lecture sessions, students took a post-performance test.

4 RESULTS

4.1 Effect on students' behavioral engagement in science

According to Table 1, the t-value for behavioral engagement is 2.691, with a two-tailed significance (sig) of 0.009, which is less than 0.05. This result suggests that there is a significant difference in behavioral engagement between the EG and the CG. This reflects that the online IBL is effective in improving secondary school students' behavioral engagement in science learning.

Table 1. Comparison of students' behavioral engagement post-test in science within CG and EGs

	Group	N	Mean	SD	t	p
Behavioral engagement	EG	45	67.400	9.345	2.691	.009
	CG	45	61.911	9.992		

4.2 Effect on students' performance in science

Table 2. Comparison of students' pre- and post-performance test in science within CG and EGs

Group	Performance-Test	Mean	N	SD	t	p
EG	Pre-test	3.18	45	1.736	–34.558	.000
	Post-test	28.222	45	5.346		
CG	Pre-test	3.27	45	1.737	–21.985	.000
	Post-test	25.333	45	7.329		

Table 3. Comparison of post-performance test between EG and CGs

	Group	N	Mean	SD	t	p
Post-performance	EG	45	28.222	5.346	2.14	.036
	CG	45	25.333	7.329		

According to Table 2, For the EG, the t-value for the difference between pre-test and post-test scores is –34.558, with a p-value of 0.000, which is less than 0.05. This indicates there is a significant difference between pre-test and post-test scores in the EG. Furthermore, the mean score of pre-test for the EG is 3.18, while the mean score of post-test is 28.222, indicating that students' performance has a significant improvement in post-test scores compared with pre-test. Similarly, for the CG, the t-value for the difference between pre-test and post-test scores is –21.985, with a p-value of 0.000, which is also less than 0.05. This suggests a significant difference between pre-test and post-test scores in the CG. The mean score of pre-test for the CG is 3.27, and the mean score of post-test is 25.333, indicating a significant increase in scores from pre-test to post-test. In summary, both the EG and CG showed significant differences in pre-test and post-test scores, with post-test scores being significantly higher than pre-test scores. This reflects that the performance of students in both the EG and CG was significantly improved after formal teaching. Moreover, students' performance in EG with IBL pedagogical imposed for online learning environment strategy is higher than that in CG without IBL pedagogical strategy imposed for online learning environment.

From the Table 3, it can be observed that the t-value for post-performance test is 2.14, with a two-tailed significance level (sig) of 0.036, which is less than 0.05. This data suggests that there is a significant difference in students' post-performance test between the EG and CG. This reflects that the EG with an online IBL design is more effective than the CG with a power point in improving secondary school students' performance in science learning.

5 DISCUSSION

This study evaluated the effectiveness of online IBL on secondary school students' behavioral engagement and performance in science. The researcher found that secondary school students' behavioral engagement in science can be improved through an appropriate online IBL environment designed by the instructor. Moreover, the final test scores of students in the EG were improved overall compared to the CG, which means that online IBL has potential in the aspect of improving students' learning performance. These results of the current study are consistent with prior studies [59] and [60]. The use of online IBL pedagogy design to support students' behavioral engagement and performance in science learning is based on the fact that students construct their own knowledge by self-inquiry and doing. This is Dewey's idea of learning by doing and inquiry learning [61]. Another reason behind this positive result may be that online IBL provides students with a visualization of the inquiry environment to encourage them toengage in science learning. A recent study has shown that sophisticated technology can provide students with an intensive learning environment if it is integrated into a suitable pedagogy [62], which is beneficial to the improvement of students' engagement [63]. The evidence coming from Chou et al. (2022) has indicated that online skeuomorphic physics IBL with simulation significantly accelerates students' scientific inquiry competency compared with online skeuomorphic physics IBL without simulation [64].

6 CONCLUSION

The current study examined the effectiveness of online IBL on secondary school students' behavioral engagement and performance. The results of this study show that there are significant differences in students' behavioral engagement and performance between the group using an online IBL pedagogy design and the group using a traditional power point slide. The EG using IBL design in online science learning is performed better than the CG in behavioral engagement investigations and post-performance tests. This study result shows that online IBL has a significant impact on secondary school students' behavioral engagement and performance in science subjects. In this regard, it can be concluded that students' behavioral engagement and performance in online science learning can be improved through the pedagogy designed by the instructor. The result of this research will contribute to teacher instructional design in the future.

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