The Effect of Interface Instrumentation Experiments-Supported Blended Learning on Students' Critical Thinking Skills and Academic Achievement

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Abstract—This study aims to promote students' critical thinking skills and academic achievement using Interface Instrumentation Experiments-supported Blended Learning (IIE-BL). In this quasi-experimental study, 40 undergraduate students who took the Basic Physics II course from the Department of Physics Education at two private universities in Indonesia were assigned randomly as experimental and control groups. Experimental group students were taught using blended learning based on interface instrumentation technology, while the control group students were taught using conventional learning by the same lecturer. To collect data, the Critical Thinking Test (CTT) and Physics Achievement Test (PAT) were administered, which data were then analyzed in independent and paired *t*-tests, as well as the *d*-effect sizes test on SPSS 26 at a significance level of 0.05. The results showed that students in the experimental group obtained significantly higher critical thinking skills and achievement scores than students in the control group. It can be concluded that IIE-BL is effective in improving students' critical thinking skills and achievement in the Basic Physics II course. Educators are suggested to apply IIE-BL to promote student performance and catalyze their learning.

Keywords—interface instrumentation experiments, blended learning, critical thinking skills, academic achievement

1 Introduction

The advancement of technology has brought significant impacts on human life, including in the field of education. Technology assists educators in delivering materials to students without being limited to a physical classroom setting. Technology has been extremely supportive in facilitating learning, especially during the COVID-19 pandemic where e-learning is widely used. WhatsApp, Zoom Meeting, and other platforms can function as online learning platforms which facilitate distance learning. Blended learning becomes popular as it combines face-to-face meetings and online learning. Blended learning also provides relevant strategies that can help students make optimal academic achievement [1]. Blended learning is an alternative approach to learning during the COVID-19 pandemic [2] where learning has shifted to e-learning [3]. WhatsApp group applications facilitate the flipped classroom as it provides chatrooms and WhatsApp call features [4]. WhatsApp has been one of the most commonly used platforms for learning activities during the COVID-19 pandemic besides Google Classroom, and Zoom Meeting [5].

Learning Management System (LMS) is another online learning platform that can assist educators in delivering teaching materials that requires an Internet connection [6]. Unfortunately, due to expensive internet packages, uncooperative students, and low student attendance rates, the use of LMS in for learning is more challenging [7]. Therefore, WhatsApp groups can be used to support LMS in online learning by making the communication between teachers and students more efficient. Communication between the teacher and students using WhatsApp groups does not require a massive internet package, making it easier for students to participate in online classes. WhatsApp is an effective communication tool for overcoming communication barriers [8] and it allows students to learn anywhere. In addition, students have a positive perception of the use of WhatsApp as a teaching medium and learning platform [9] and WhatsApp groups can also be developed as an m-learning tool [10]. Furthermore, WhatsApp can be utilized as an online debate medium to enhance students' critical thinking skills during the COVID-19 pandemic [11].

Critical thinking skill is a part of 21st-century higher-level thinking skills [12] that are associated with students' success in the future [13]. Critical thinking skills in physics experiments assisted by technology and instrumentation interfaces for students are one of important thinking skills that help students solve physics problems. The physics experiment device assisted by technology and instrumentation interfaces combines software and hardware to visualize physics experiment data. Physics experiment activities are conducted online and offline during the COVID-19 pandemic by utilizing physics experiment devices assisted by technology and instrumentation interfaces, involving Arduino devices and LabVIEW. Arduino devices can be used as learning media in physics education as they allow the observation of natural phenomena using sensors. The curriculum for 21st-century skills should integrate students with Arduino technology in physics experiments to improve students' learning interests [14] which will bring a positive influence on education [15]. Arduino is a relatively inexpensive microcontroller that is widely used by teachers [16]. The application of Arduino in basic physics laboratories can affect students' attitudes toward performing group works [17].

The instrumentation interface is developed from Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) software that serves the data processing and visualization. Physics simulations based on LabVIEW explain difficult materials that are not easy to be learned in conventional laboratories [18]. LabVIEW-based instrumentation interfaces can perform graphic simulations and can be connected to Arduino devices [19]. LabVIEW and Arduino can serve as media for physics experiments in the laboratory [20]. LabVIEW-based instrumentation interfaces and electronic Arduino devices in physics experiment activities can improve students' critical thinking skills and academic achievement in physics. Physics experiments using the interaction of hardware and software are practical [21] and such experiments can be the alternative to conventional physics experiment devices. The advancement of technology indeed has changed the roles of teachers into figures of intermediaries, facilitators, and guides through digital learning that functions as the main device in the education aspect [22]. Nowadays, popular cellphone applications are more attractive among 21st-century students, thereby teachers must be able to adopt technology in their teaching [23].

Virtual technology used in physics laboratory experiments has a significant effect on students' knowledge [24]. Along with the advancement of technology, teachers are also demanded to improve educational services in order to improve the quality of education. Improvement in educational services will affect the increase in student academic achievement [25]. The use of technology can increase motivation and academic achievement [26]. The interface instrumentation technology displays natural phenomena on a computer screen. Digital technology has a positive influence on increasing the academic achievement of physics education students. Digital technology also provides benefits for learning activities in higher education because students are encouraged to be more active, constructive, and interactive so as to increase academic achievement [27]. Physics experimental devices that apply technology allow more effective comprehension and good academic achievement [28]. Visual-based technology can improve students' skills and academic achievement [29].

The COVID-19 pandemic has affected the teaching and learning activities in the world, with no exception from primary education to higher education. The pandemic has shifted the learning activities into online learning [30], [31]. Universities were also compelled to terminate face-to-face learning and adopt online learning [32]. Predictions about the future of higher education vary, including predictions of dramatic and revolutionary changes. Some experts believed that incorporating technology in education could positively affect the expansion and equity of education [33]. However, the restrictions prevent learning activities from being optimally carried out, resulting in a decline in science students' critical thinking skills and learning outcomes [34].

Researchers conducted a study to address the aforementioned issues by implementing interface instrumentation experimental devices in basic physics courses offered through blended learning using e-learning applications and WhatsApp. In-person physics experimental activities were carried out on interface instrumentation experimental devices. This study examined the effects of blended learning based on interface instrumentation experiments on students' critical thinking skills and academic achievement of physics education. In relation to the research objectives, four research questions were formulated as follows:

1. Is there any statistically significant gap in students' average critical thinking skills between the experiment group and the control group?
2. Is there any statistically different findings in the average scores of students' academic achievement between the experimental group and the control group?

2 Literature review

2.1 Blended learning

Blended learning refers to the combination between face-to-face learning and online learning [35] to support unique interpretations from groups of students and use as a variety of learning resources in carrying out discussions [36] [37] to support excellent learning quality [38]. Some supporting factors and constraints follow the implementation of blended learning related to the smoothness of communication, discipline function, rewind learning, media adaptation, and learning programs [39]. Face-to-face learning is carried out in the classroom while online learning utilizes internet facilities and online discussion forums [40]. Online learning can use LMS supported by the WhatsApp group application. Meanwhile, face-to-face learning can be done in the classroom or laboratory. Blended learning can make classroom attendance more efficient while it maintaining the learning plans and providing effective teaching experiences [41].

Blended learning combines synchronous and asynchronous learning to facilitate effective learning activities. The synchronous learning was conducted on Zoom meetings where direct interaction between students and lecturer occurred, while asynchronous learning through YouTube videos facilitated indirect interaction [42] [43]. Synchronous learning activities were real-time, while asynchronous activities can be completed at different times [44]. Popular synchronous and asynchronous communication tools used worldwide include Google Classroom, Microsoft Teams, Cisco, Webex, Zoom, and Moodle [45]. WhatsApp can also facilitate both synchronous and asynchronous learning communication [46] and it is an interactive technology tool that fosters dynamic, engaging, interactive, and independent learning to support students in acquiring meaningful knowledge [47]. In this study, LMS in the form of Moodle and WhatsApp groups were employed for online learning, while face-to-face learning is facilitated by interface instrumentation technology.

2.2 Interface instrumentation technology

Interface instrumentation technology interacts with the software and hardware. In this study, the Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) is the software that is integrated to the hardware in the Arduino board. LabVIEW controlled the Arduino in performing measurements [48]. Arduino microcontroller control and several electronic components were controlled via a computer using the LabVIEW interface [49]. The interaction between LabVIEW and Arduino software is part of a data acquisition system that can be developed into an experimental device for students in the laboratory [50], [51], [52] as a modern experimental equipment [53].

LabVIEW is a graphical interface device that facilitates the easy ordering and acquisition of data from Arduino [55]. LabVIEW connects the Arduino control board to sensors and transmits data from the Arduino hardware to the LabVIEW program designed for experiments [54]. Arduino serves as a data acquisition system that can be controlled by LabVIEW to conduct experiments [56]. The use of Arduino-based LabVIEW interaction is a modern experiment, as it utilizes a computer-based control system [57]. The computer system equipped with LabVIEW software controls the processing of information obtained from the Arduino hardware [58]. In this study, physics experiments were carried out using the LabVIEW software interaction designed to abridge the electronic devices installed on the Arduino board. Physics experiments in this study were carried out on the material of the diffraction grating, the intensity of the Light Emitting Diode (LED) light, and the thickness of the plastic material.

2.3 Critical thinking skills

Critical thinking skills are part of higher-order thinking skills. Critical thinking skills are major skills to acquire through learning process [59]. Critical thinking is a thinking process that directs all knowledge and skills in solving problems, making decisions, analyzing problems, and conducting research based on the information and data obtained to draw comprehensible conclusions [60]. Students need to develop strong critical thinking skills to understand information, solve problems in everyday life, make decisions logically, think reflectively, and have an initial knowledge about the problems [61]. As one of the 21st century skills, the critical thinking skill should be developed through meaningful learning experiences [62]. The use of inquiry-discovery method has been capable of improving students' critical thinking skill [63]. The integration of inquiry-based learning approach for science subject can stimulate students' critical thinking skills [64].

The inquiry-based learning can enhance critical thinking skills by improving students' abilities to interpret, analyze, evaluate, infer, explain, and self-regulate the information that they acquire. These are the core skills of critical thinking [65]. A teacher should possess adequate critical thinking skill in order to be capable of teaching these abilities to the students [66]. Engaging students in inquiry-based science activities, the lecturer can help students develop their critical thinking skills [67]. In addition, experimental activities conducted in the laboratory using an inquiry-based approach can also foster critical thinking skills in students [68]. In this study, students' critical thinking skills were measured using a rubric developed by Hohmann and Grillo [69] based on several indicators: questions and problems, information, intellectual persistence, and intellectual independence. Assessment of students' critical thinking skills was carried out in two stages before and after the lectures.

2.4 Academic achievement

Academic achievement describes the knowledge, skills, values, and attitudes acquired and demonstrated by students as part of educational outcomes through a learning process based on cognitive, socio-emotional, and behavioral domains [70]. The constructivism theory applies the subjective principles that allow for different interpretations and can lead to varied learning outcomes [71]. Schools and other education programs need to directly promote academic development and indirectly enhance students' cognitive development by prompting cognitive-academic direction [72]. Learning outcomes are affected by the interaction between educators and students, where educators play a crucial role in enhancing student achievement [73].

Improving students' learning outcomes requires teachers to apply student-centered learning method and integrate the technology to facilitate learning activities. Computer-based learning provides opportunities for students to participate actively, increase their curiosity, and achieve higher academic performance in physics [74]. Integrating Information and Communication Technology (ICT) into teaching and learning processes through the use of digital learning tools can improve students' academic achievement [75]. Some factors influence students' academic achievement, including the learning method [76]. Computer-based learning media can be used to improve students' academic achievement [77]. Meanwhile, online laboratory learning also enhances academic achievement [78], [79], [80]. Furthermore, blended learning, the use of science experiments and the use of technology that assists learning can also increase students' academic achievement [81], [82].

3 Methods

This section describes the research method, samples, instruments, and data analysis used to measure students' critical thinking skills and academic achievement.

3.1 Design

This quasi-experimental study was conducted at two private universities in Mataram City, West Nusa Tenggara province, Indonesia. Blended learning based on interface instrumentation technology was applied in the experimental group, while the control group was taught using conventional learning by the same model teacher. The researchers observed how the lecturer taught during the treatment. In this study, blended learning based on interface instrumentation experiments is the independent variable, while critical thinking skills and academic achievement are the dependent variables. The research was carried out in the even semester of the 2020/2021 school year in six meetings with 100 minutes each. The learning topics were the diffraction grating, the intensity of the LED light to the rotating angle, and the thickness of the plastic material to the intensity of the LED light. Data were analyzed using descriptive and inferential statistical analysis. *t*-test was carried out to analyze the influence, while Cohen's *d* was employed to determine the gap before and after learning.

3.2 Samples

Samples of this study were 40 students from the Department of Physics Education at two private universities in the city of Mataram, West Nusa Tenggara province, Indonesia. The two universities were selected using a convenience sampling technique. One of the classes (22 students) was randomly assigned as the experimental group, while the other class (18 students) was assigned as the control group. Samples aged between

18 to 21 years. There were 9 males and 13 females in the experimental group, while the control group consisted of 4 males and 14 females.

3.3 Data collection instruments

The Critical Thinking Test (CTT) developed by Hohmann and Grillo [69] was used to assess students' critical thinking skills. Meanwhile, the Physics Achievement Test (PAT) was used to measure student academic achievement. The Delphi technique was used for CTT and PAT validation to gather expert views regarding the instrument being developed [83]. CTT is a rubric used to measure students' critical thinking skills before and after learning. Domains in CTT consist of questions and problems, information, intellectual persistence, and intellectual independence. The rubric was validated for its instrument instructions, language, writing, and aspects of critical thinking skills by relevant experts. Experts' suggestions were then applied to improve the instrument and to determine the validity and reliability coefficients of the instrument. The validity of the instrument was measured using the Gregory formula [84], while the reliability was calculated using Cohen's Kappa formula [85]. The validity of the CTT was 1.00 (high) and the reliability of 1.00 with an approximate significance of 0.000 (<0.05). Hence, the CTT can be regarded as valid and reliable.

PAT consisted of five open-ended questions to predict the wavelength, the distance between slits, and the band distance to the m-order to the central light on the diffraction grating. Students were required to predict the diffraction phenomenon of monochromatic light and the magnitude of the LED light intensity for various angles of incidence on the surface of the light sensor and proved the thickness of the plastic through light absorption. The PAT instrument was validated by experts to measure the validity and reliability of the instrument. The validity of the PAT was 1.00 and Cronbach's alpha reliability was 0.68. Therefore, PAT was regarded as valid and reliable.

3.4 Procedures

Treatment in the experimental group. There were six meetings for the experimental group, each of which consisted of three stages: introduction, core, and closing. Meeting 1 (lecturers and students carried out teaching and learning activities face-to-face), preliminary activity (5 mins.): The lecturer explained the learning objectives and learning materials. Core activity (90 mins.): Pre-test was performed and students were given usernames to log in to their e-learning accounts. Students listen to the lecture about statistical analysis for physics experiments and material and conducted discussions on the e-learning portal and the WhatsApp Group application. Closing activity (5 mins.): the lecturer assessed the thinking processes and gave assignments for students to be later performed on the e-learning portal or WhatsApp Group. Meeting 2 and Meeting 3 (online learning session), preliminary activity (15 mins.): the lecturer explained the learning objectives and learning materials. Core activity (70 mins.): lecturer helped students to understand the material and experimental analysis. Problems and hypotheses physics were also given to students through the e-learning portal on the www.perkuliahanfisia.com page. Closing activity (15 mins.): the lecturer made reflections and feedback and reviewed conclusions and assignments through chats. Students were also directed to download practicum guidelines and used interface instrumentation experiments on the portal e-learning. Meeting 4 (classroom session), preliminary activity (15 mins.): the lecturer re-explained the objectives of the practicum using interface instrumentation experiments and the functions of interface instrumentation experimental devices used as learning media in the laboratory. Core activity (70 mins.): the lecturer directed students to conduct experiments using the experimental instrumentation interface provided, and the lecturer asked questions about data collection. Closing activity (15 mins.): the lecturer evaluated the activities and asked students to make reviews and conclusions regarding the materials that they had learned, the task of making a practicum report, and discussed data analysis related to use through the e-learning portal or WhatsApp (practicum assistant). Meeting 5 (online session), preliminary activity (15 mins.): the lecturer explained the purpose of data analysis, and the function of the interface instrumentation experimental device used as a learning medium in the laboratory. Core activity (70 mins.): the lecturer explained the data analysis that would be used in practicum reports (online student guidance to analyze experimental results). Closing activity (15 mins.): the lecturer evaluated the activities and students submitted their practicum reports through their respective accounts on the e-learning portal or the WhatsApp application to be assessed. After that, a post-test was conducted. Meeting 6 (offline session) was the post-test. Students' scores were published on their Moodle.

Treatment in the control group. Six meetings consisting of three stages each were performed. Face-to-face learning activities were conducted via Zoom meetings due to the COVID-19 pandemic. Meeting 1, preliminary activity (5 mins.): The lecturer explained the learning objectives and the material to be studied. Core activity (90 mins.): pre-test was conducted followed by an explanation of statistical analysis for physics experiments. Furthermore, the lecturer explained the materials of the diffraction grating, the intensity of the LED light to the rotating angle, and the thickness of the plastic material to the intensity of the LED light which would be studied and discussed at the next meeting. Closing activity (5 mins.): the lecturer made an evaluation and gave assignments to students to study practicum materials. Meeting 2, preliminary activity (15 mins.): the lecturer explained the learning objectives of the material on the diffraction grating and the intensity of the LED light on the rotating angle to students. Core activity (70 mins.): the lecturer explained the material on the diffraction grating and the intensity of the LED light on the rotating angle and gave some problems and opportunities for students to hypothesize the problems. Closing activity (15 mins.): the lecturer evaluated the learning, provided feedback, reviews, and conclusions, as well as assignments to students about the material that has been studied. At meeting 3, students studied the thickness of the plastic material against the intensity of the LED light. The preliminary, main, and closing activities were the same as the second meeting. Meeting 4, preliminary activity (15 mins.): the lecturer re-explained the objectives of the practicum using conventional experimental devices used as learning media in the laboratory. Core activity (70 mins.): experiments were conducted using conventional devices that have been provided followed by a question and answer session. Closing activity (15 mins.):

the lecturer made the evaluation and asked for students' reviews and conclusions regarding the material being practiced. Next, the lecturer assigned the students to write practicum reports and discuss data analysis (face-to-face-based practicum assistance using the zoom meeting application). Meeting 5, preliminary activity (15 mins.): the lecturer explained the purpose of data analysis. Core activity (70 mins.): the lecturer explained the data analysis that would be used in the practicum report. Closing activity (15 mins.): the lecturer evaluated the learning and students submitted practicum reports to be assessed. Meeting 6 was the post-test. Preliminary activity (5 mins.): the lecturer asked students to pray and then explained the exam rules. Core activity (90 mins.): lecturer distributed the post-test questions to students. Closing activity (5 mins.): the lecturer informed the results of the student's final grades through the study program announcement board.

3.5 Data analysis

Students' critical thinking skills were measured based on an assessment rubric before and after learning activities. The *t*-test examined the differences in pre-test and post-test data between the experimental and control groups, while Cohen's *d* measured the increase in students' pre-test and post-test scores. Normality and homogeneity tests had been first conducted prior to the *t*-test.

The normality and homogeneity of the data were tested in the Shapiro-Wilk test and Levene's test. Table 1 presents the pre-test and post-test scores on critical thinking skills and academic achievement, showing that data were normally distributed and homogeneous ($p > 0.05$), thereby *t*-test could be performed. An independent *t*-test was conducted to see any statistically significant difference in the average critical thinking skill scores between the experimental group and the control group. Paired samples *t*-test was carried out to find increases in critical thinking skills after treatment. The gap in students' critical thinking skill scores before and after treatment was measured using the effect size (*d*) [86]. Cohen's *d* value describes the length of the gap in students' critical thinking skill scores before treatment and after treatment. These coefficients were grouped into four: 0.20 to 0.40 (small), 0.50 to 0.70 (moderate), 0.8 to 1.2 (large), and greater than 1.30 (very large) [87]. Statistical analysis was performed using SPSS 26 software at a significance level of 5%.

Table 1. Normality and homogeneity tests on students' pre-test and post-test scores for critical thinking skills and academic achievement

Variable	Groups	Pre-test		Post-test	
		Normality	***Homogeneity***	***Normality***	***Homogeneity***
Critical thinking	Experimental	0.107	0.956	0.111	0.856
	Control	0.209		0.150	
Achievement	Experimental	0.287	0.580	0.313	0.098
	Control	0.364		0.453	

Note: $p > 0.05$ = Data are normally distributed and are homogenous

4 Results

The significant difference in the average scores of student's critical thinking skills between the experimental group and the control group was measured in the independent sample *t*-test. The *t*-test compared students' initial abilities and average scores of critical thinking skills between the experimental group and the control group as summarized in Table 2. No significant difference was found in students' initial abilities related to critical thinking skills between the experimental group and the control group. The critical thinking skills test was based on the framework proposed by Hohmann and Grillo [69] consisting of questions and problems, information, intellectual perversion, and intellectual autonomy. In general, there was no statistically significant difference in the overall mean score pre-test between the experimental group and the control group ($t(40) = -0.124$; $p = 0.902$). Hence, students had equal initial critical thinking skills.

Table 2. The gap in the pre-test scores between the experimental and control groups for critical thinking skills

Group	n	M	SD	*t*	*p*
Experimental	22	37.216	7.081	-0.124	0.902
Control	18	37.500	7.426		

Note: $p > 0.05$ = no significant difference

The results of the *t*-test for students' final scores were compared with the average scores of critical thinking skills between the experimental group and the control group as summarized in Table 3. There were differences in students' final critical thinking skills between the experimental group and the control group. There was a statistically significant difference in the overall post-test mean scores between the experimental and control groups ($t(40) = 8.772$; $p = 0.000$).

Table 3. The gap in the post-test scores between the experimental and control groups for critical thinking skills

Group	n	M	SD	*t*	*p*
Experimental	22	87.500	6.954	8.772	0.000
Control	18	68.750	6.431		

Note: $p < 0.05$ = there is a significant gap

The second research question on whether there is a significant difference between the pre-test and post-test average scores of students' critical thinking skills which were answered in the paired sample *t*-test. In addition, the effect of interface instrumentation experiment-based blended learning on students' critical thinking skills was reflected in Cohen's *d* scores as presented in Table 4.

Table 4. The gap in the pre-test and post-test scores between the experimental and control groups on critical thinking skills

Group		M	SD	*t*	*p*	Cohen's *d*
Experimental	Pre-test	37.216	7.081	-44.718	0.000	7.165
	Post-test	87.500	6.954			
Control	Pre-test	37.500	7.426	-13.186	0.000	4.499
	Post-test	68.750	6.431			

Students' average score in critical thinking skills for the experimental group increased from pre-test to post-test. There was a significant difference found between the mean pre-test and post-test scores of the experimental group from 37.216 to 87.500 (increased by 50.284; $t = -44.718$; $p = 0.000$), while for the control group, it increased from 37.500 to 68.750 (increased by 31.250; $t = -13.186$; $p = 0.000$). Based on the results of the paired *t*-test, students in the experimental group showed an increase in the average value of critical thinking skills greater than that of the control group after the treatment. The effect size of the intervention on critical thinking skills in the experimental group was 7.165 and in the control group was 4.499. Therefore, the instrumentation experiments-supported blended learning interface is more effective in promoting students' critical thinking skills compared to conventional learning.

To answer the first research question on the presence of a significant difference in the average academic achievement scores of students between the experimental and control groups, an independent sample *t*-test was employed. The results of the *t*-test for students' initial abilities obtained were compared with the average academic achievement scores between the experimental group and the control group which s summarized in Table 5. There was no difference in students' initial abilities related to academic achievement between the experimental group and the control group. In general, no statistically significant difference was found in the overall pre-test mean scores between the experimental and control groups ($t(40) = 0.000$; $p = 1.000$). Therefore, students' academic achievement at the beginning of the lecture was equal.

Table 5. The gap in pre-test scores between experimental and control groups for academic achievement

Group	n	M	SD	*t*	*p*
Experimental	22	30.000	5.623	0.000	1.000
Control	18	30.000	6.174		

Note: $p < 0.05$ = there is a significant gap

The results of the *t*-test for students' final scores were compared to the average academic achievement scores between the experimental group and the control group as summarized in Table 6. There were differences in students' final scores between the experimental group and the control group. In general, there was a statistically significant difference in the post-test scores obtained by the experimental and control groups ($t(40) = 9.402$; $p = 0.000$), indicating that the academic achievement of students after the treatment differed.

Table 6. The gap in post-test scores between experimental and control groups for academic achievement

Group	n	M	SD	*t*	*p*
Experimental	22	80.364	7.188	9.402	0.000
Control	18	61.556	4.973		

Note: $p < 0.05$ = there is a significant gap

The presence of a significant difference between the average scores of students' pre-test and post-test academic achievement was measured in a paired sample *t*-test. The effect of interface instrumentation experiment-based blended learning on student academic achievement was seen in Cohen's *d* values as presented in Table 7.

Table 7. The gap in the pre-test and post-test scores between experimental and control groups for academic achievement

Group		M	SD	*t*	*p*	Cohen's *d*
Experimental	Pre-test	30.000	5.623	-74.158	0.000	7.805
	Post-test	80.364	7.188			
Control	Pre-test	30.000	6.174	-23.744	0.000	5.629
	Post-test	61.556	4.973			

The average academic achievement score of the experimental group students has increased from pre-test to post-test. The average pre-test and post-test academic achievement scores for the experimental group significantly increased from 30,000 to 80,364 (an increase of 50.364; t = -74.158; p = 0.000), while for the control group, it increased from 30.000 to 61,556 (an increase of 31.556; t = -23.744; p = 0.000). The paired *t*-test shows that students in the experimental group had higher average academic achievement scores than that of the control group after the treatment. The effect size of the treatment on achievement in the experimental group was 7.805 and in the comparison group was 5.629. It can be concluded that the instrumentation experiments-supported blended learning interface is more effective in promoting students' academic achievement than traditional learning.

5 Discussion

This study examined the effect of blended learning based on interface instrumentation experiments on students' critical thinking skills and academic achievement compared to the application of conventional learning. The independent sample *t*-test showed a significant difference in the critical thinking skills between students in the experimental group and the control group. The experimental group taught using blended learning based on interface instrumentation experiments had an average value of critical thinking skills greater than the control group. Positive support during lecture activities contributed to the findings of this study [88]. Students carried out discussions and worked in groups to design, investigate, and communicate research results so that building their knowledge is learning based on constructivism. Inquiry-based learning activities are active learning strategies that can improve critical thinking skills [89]. Blended learning can enhance students' knowledge and make learning more efficient, effective, and interesting [90]. Blended learning based on project-based learning can improve students' thinking skills, including independent thinking, critical thinking, and creative thinking skills better than conventional learning [91]. Blended learning based on inquiry activities appears as the most significant treatment compared to real and virtual experiments [92]. The use of technology is one of the factors and measurements in increasing students' academic achievement [93].

The findings of this study confirm the findings in previous studies stating that blended learning and experimental technology based on interface instrumentation are more effective than conventional learning (blended learning for example [94], [95], [96], [97], [98], [99], [100]; experimental technology based on interface instrumentation [101], [102], [103], [104], [105]). This finding makes sense because the blended learning interface instrumentation experiment is one of the 21^{st}-century learning following technological development 4.0. Furthermore, blended learning promotes critical thinking skills and academic achievement during the COVID-19 pandemic [106]. Blended learning is an alternative solution to overcome the shortcomings of face-to-face learning to provide effective, efficient, and fun learning [107]. Blended learning provides a positive role and makes students more independent in carrying out learning [108].

The results of the paired sample *t*-test showed an increase in the scores of students in the experimental group. Cohen's *d* scores on critical thinking skills and academic achievement showed that the use of blended learning based on interface instrumentation experiments is more effective than conventional learning. Blended learning is an effective method for improving critical thinking skills and academic achievement in physics learning [106], [109]. The development of software and hardware interaction as an experimental instrumentation media interface can increase cost efficiency and it allows a better comprehension of physics [110]. Computer-assisted physics instrumentation also helps students gain knowledge about programming and instrumentation, as well as increasing students' self-confidence and motivation to learn physics and programming languages [101]. Hammoumi et al [111] claim that instrumentation techniques provide easy access to collected data for further analysis. Likewise, Suwondo and Sulisworo [112] found the interaction of LabVIEW software and Arduino hardware effective in learning physics. Ishafit et al. [113] found the Arduino and LabVIEW system a solution to the limited access to experimental devices as a physics learning medium which provides opportunities for students to control instrumentation devices and conduct real-time experiments remotely using the website.

On the other side, students in the control group also improved their critical thinking skills and academic achievement. However, the average score of the experimental group is greater than the average score of the control group. Teaching and learning activities that utilize information and communication technology are believed more effective in improving the critical thinking skills and academic achievement of students. Student-centered technology enables student-student interaction and lecturer-student interaction which can increase academic achievement better than using conventional laboratories [114]. In addition, Karmakar [115] also found virtual instrumentation and ICT capable of increasing students' learning interest through direct experiments. Remote laboratory activities using the interaction between software and hardware positively contribute to cognitive, behavioral, and affective academic achievement [116]. The blended learning was performed using the interface instrumentation experiments by combining online and face-to-face learning both synchronously and asynchronously, using Moodle and WhatsApp. The face-to-face learning was conducted in the physics laboratory, where interface instrumentation experiments were conducted using the Home and Student version of LabVIEW software and electronic devices installed on Arduino.

It was further explained that students acquire conceptual knowledge, can be directly involved in the laboratory, and are satisfied with distant learning that utilizes the interaction of software and hardware. Thus the physics experimental set is a factor that influences the critical thinking skills and academic achievement of students in both groups in this study. One of the challenges was to familiarize students with the use of ICT in learning activities, particularly in the context of LabVIEW software and Arduino hardware development. It is essential to introduce these technologies to students to get them familiar with ICT in supporting both classroom learning and the physics laboratory sessions.

6 Conclusions

This study revealed that students in the experimental group had significantly higher scores than those in the control group as shown by statistically significant gap in the mean scores of students' critical thinking skills between the two groups. A statistically significant gap was also found in the average academic achievement of students between the two groups, in favor of the experimental group.

This study concludes that blended learning based on interface instrumentation experiments is better at improving students' critical thinking skills and academic achievement than conventional teaching. Blended learning based on interface instrumentation experiments is a constructivist learning method that is effective in improving students' critical thinking skills and academic achievement in Basic Physics II courses. This method provides students the opportunity to integrate Basic Physics II material into interactive learning media based on LabVIEW and Arduino into the physics experiment process.

In the broader context, the use of interface instrumentation experiment-based blended learning positively contributes to students' success in higher education and in their professional domain. Therefore, blended learning based on interface instrumentation experiments should be included in the higher education curriculum, particularly in the teaching and learning activities during the COVID-19 pandemic. Furthermore, interface instrumentation helps students solve problems in everyday life by utilizing and implementing robotic industrial devices. More importantly, this research can be used as a guide for physics educators to design and implement more effective instruction in

Basic Physics courses that can be applied during the COVID-19 pandemic. These results can also be implemented in an optics course to provide a more contextual learning experience. In addition, this study also provides new insights about effective Basic Physics teaching strategies for lecturers and higher education institutions on how to significantly improve students' critical thinking skills and academic achievement using blended learning based on interface instrumentation experiments.

This study involved university students as samples in a small-scale experiment. Future researchers are suggested to involve a larger number of participants to make the findings generalizable and to gain more significant results by extending the implementation of the blended learning method based on interface instrumentation. In addition, this study focuses only on students' critical thinking skills and academic achievement of students. Therefore, future researchers may examine the effect of the blended learning method based on interface instrumentation experiments to improve students' practical skills and scientific attitudes and gain more comprehensive findings. In addition, future researchers can also compare the effectiveness of blended learning models based on interface instrumentation experiments to other non-conventional teaching methods. Since this study is the first study that investigated the effect of blended learning based on interface instrumentation experiments on students' critical thinking skills and academic achievement in the Basic Physics II course, the findings of this study add up to the body of knowledge in the field of learning and technology and open up new directions for future research.

7 Limitations

Based on the results of the research, it is hoped that it can help educators and researchers, especially in the field of physics education, regarding blended learning models and learning in laboratories assisted by software and hardware interaction in publishing and carrying out their work in the field of learning technology. Although this research as a whole succeeded in improving critical thinking skills and learning outcomes of physics education students, some limitations of this study need to be concerned. This study involved limited number of students for only the Basic Physics II course. Future researchers need to involve larger number of participants and conduct the experiment on advanced physics courses as there will be more laboratory experiments to be conducted. More face-to-face learning can be applied to optimize the physics experimental activities. This present study only regarded quantitative data, thereby future researchers are encouraged to use qualitative data for more comprehensive results. In addition, this research only improves critical thinking skills and learning outcomes. Future researchers are advised to involve a larger number of participants so that their findings can be generalized and in order to obtain a more significant effect. The blended learning model based on interface instrumentation experiments can be applied. Furthermore, it is also recommended for different physics materials. Future researchers are also expected to test the effect of the blended learning model based on interface instrumentation experiments to improve the practical skills and scientific attitudes of physics education students and to obtain more comprehensive findings. In addition, future studies need to compare the effectiveness of blended learning models based on interface instrumentation experiments with other non-conventional teaching methods.

8 References

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