Online-Journals.org

iJOE International Journal of Online and Biomedical Engineering

iJOE | eISSN: 2626-8493 | Vol. 20 No. 10 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijoe.v20i10.48031

PAPER

A Flexible Practicum Model on Education: Hybrid Learning Integrated Remote Laboratory Activity Design

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ABSTRACT

This study's objective was to create a hybrid learning-integrated remote laboratory model with validity and practicality. This model has four learning spaces, namely live synchronous, virtual synchronous, self-paced asynchronous, and collaborative asynchronous, so it can support flexible learning. Besides that, this learning model is also based on cognitivism, connectivism, constructivism, behaviourism learning theories and Bloom's digital taxonomy. The hybrid learning integrated remote laboratory model consists of six syntaxes: 1) issue; 2) investigation; 3) team discussion to solve problems; 4) experiment using a remote laboratory; 5) analysis and evaluation; and 6) explore new solutions. Focus group discussions (FGD) were used to collect high-quality data by seven experts in learning models, vocational education, language and technology. The hybrid learning-integrated remote laboratory model quality analysis used Aiken's V. The result showed that the hybrid learning integrated-remote laboratory model content is valid, with a validity value of 0.87. The practicality analysis result showed that the average percentage of the assessments from lecturers and students was 88.16%, so it can be concluded that it has a high validity value and is very practical.

KEYWORDS

hybrid learning, remote laboratory, model validity, learning activity, flexible practicum

1 INTRODUCTION

Flexibility in the learning process has become a crucial issue in the field of education during the era of the Fourth Industrial Revolution (IR4.0). The COVID-19 pandemic has brought about significant changes in the role of technology in education. Technology has accelerated the transformation of conventional learning into flexible learning [1], [2]. The demand for flexible learning continues to grow due to the lifestyle of the Z generation, which is closely intertwined with technology [3]. Findings indicate that people under the age of 35 are more inclined to use Internet of Things (IoT) services in various sectors, especially in education, as it allows both

Masril, M., Jalinus, N., Ridwan, Ambiyar, Sukardi, Irfan, D. (2024). A Flexible Practicum Model on Education: Hybrid Learning Integrated Remote Laboratory Activity Design. *International Journal of Online and Biomedical Engineering (iJOE)*, 20(10), pp. 4–17. https://doi.org/10.3991/ijoe.v20i10.48031

Article submitted 2024-01-25. Revision uploaded 2024-04-01. Final acceptance 2024-04-01.

lecturers and students to save time by attending classes online from anywhere [4]. This is also supported by data analysis by Asarta and Schmidt, which shows that students have reduced their average classroom attendance to between 49% and 63% because they prefer online meetings [2]. Other findings also indicate a rapid improvement in student enrolment in online classes [5], [6]. Therefore, higher education institutions are considering offering online and blended learning formats to facilitate flexible learning [7], [2]. One of the models that support flexibility in learning is hybrid learning. Hybrid learning has become a popular and continuously evolving research topic [8]. This is in line with the view of Shinghal, who states that the hybrid learning model will no longer be an option but a necessity for every educational organisation [9]. Hybrid learning has also become a new direction in educational reform [10].

Hybrid learning is a pedagogical approach that combines face-to-face instruction with computer-mediated instruction [11], [12], [13]. Hybrid learning is based on several fundamental principles [14], such as: (1) learning is open; (2) learning is social; (3) learning is personal; (4) learning is augmented; (5) learning is multi-represented; and (6) learning is mobile. These principles make hybrid learning a model that supports flexibility because they align with Bergamin's categories of flexible learning, including time management flexibility, communication flexibility with instructors, and content flexibility [15], [5]. These principles are also in line with the traits of the Z generation, who are (1) accustomed to and heavily reliant on technology due to growing up in a technologically advanced environment; (2) the ability to multitask while using a wide range of online products and sophisticated technological tools, while also respecting simplicity and interactive design; (3) a greater sense of social responsibility due to the abundance of online information; and (4) a constant state of connectivity through social network communication across national boundaries and cultural contexts, which has an indirect impact on thought processes and decision-making [16].

The implementation of hybrid learning has five main reasons, namely: (1) it contributes to pedagogy by supporting more interactive learning strategies; (2) it promotes collaborative learning, allowing learners and educators to work together on projects from anywhere and at any time; (3) it enhances intercultural awareness by bringing together researchers, educators, and students from around the world; (4) it reduces the cost of teaching and learning, as students no longer need to make frequent commutes to complete their education; and (5) it is suitable for the learning styles of today's students [17]. This perspective is also supported by other researchers, who believe that hybrid learning is highly effective in improving learning effectiveness [18]. Other studies indicate that the implementation of hybrid learning significantly influences learning outcomes and creative thinking skills and is a suitable alternative for the demands of IR4.0 [19], [20]. Hybrid learning can also improve students' confidence in understanding the subject matter and result in better assessment outcomes in practical applications.

While some studies have explored the implementation of hybrid learning to support flexible learning, it is essential to develop a hybrid learning model that is suitable for the specific subject and desired learning outcomes [3], [21]. This is particularly important for practical learning, as hybrid learning is considered a suitable model for laboratory demonstrations [16]. Therefore, it is crucial to develop a hybrid learning model that is suitable for the learning outcomes of the subject and the characteristics of the students nowadays.

This paper describes the results of the validity and practicality of a hybrid learning model integrated with a remote laboratory for practical learning, specifically in the context of embedded systems. The choice of embedded systems as the subject is because, currently, it is important for students to have proficiency in embedded system programming, a crucial skill for a system engineer, and to improve the learning quality of embedded systems courses through a hybrid learning approach.

2 RELATED WORK

2.1 Hybrid learning

Hybrid learning includes face-to-face and synchronous online interactions [22]. While students in the classroom and those connected online work simultaneously in the hybrid learning paradigm, the hybrid modality is perceived as having two distinct teaching modalities—students engage in academic activities both at home and at school. The hybrid learning model combines the best aspects of in-person instruction with technology-based online learning by bringing together two groups of students: one through in-person instruction in classrooms and another through online platforms. Hybrid learning has placed a strong emphasis on the development of flexible learning and integrated pedagogy [20]. In order to take advantage of the benefits of both modes, the hybrid learning model also offers a setting for combining various technologies and pedagogical techniques. This model offers a way to attain pedagogical flexibility in learning; learning makes it easier to apply active strategies that promote student participation and autonomy development, and it also makes it possible to create adaptive learning strategies that cater to the needs and preferences of students [23].

2.2 Remote laboratory

One of the technological innovations that has had a big impact on education in the era of the Industrial Revolution 4.0 is the virtual laboratory. Virtual laboratories are web-based applications that can provide benefits in the learning process [24]. Virtual laboratories are now the subject of intense development with the goal of assisting students in comprehending abstract and difficult learning processes. Students can be trained to work cooperatively simultaneously from any location with the support of virtual laboratories [25]. A remote laboratory is one kind of virtual laboratory. There are benefits to using remote laboratories, such as control, real-time information visualisation, and direct equipment interaction [26]. Remote laboratories allow students to carry out practical work outside the physical laboratory by utilising Internet technology, where students can see direct feedback from the orders given by students [27]. The term "remote laboratories" refers to an online laboratory and experimental setup that still uses real, physical equipment. The user does not have to be physically co-located with the laboratory equipment in order to conduct live experiments over the internet from almost anywhere at any time. Users can define, start, stop, pause, and repeat the experiment just as if they were close to the equipment. Thus, these teleoperated online laboratories have benefits, especially with regard to the time and place of experimentation. Additionally, it gives students the chance to thoroughly customise their preparation for or review of an in-person laboratory course. A subset of online laboratories that use previously made video recordings of the experiment are also referred to as remote laboratories [28].

The potential benefit of remote laboratories is that students can carry out experiments flexibly and effectively.

3 MATERIALS AND METHODS

3.1 Objective of this study

The main objective of this study is to produce a high-quality hybrid learning model integrated with a remote laboratory for embedded system practice (content validity and practicality). Content validity is assessed based on current knowledge [21], [29]. Meanwhile, practicality is assessed based on user group responses to determine if the representatives of the target group of users consider the intervention to be usable and if it is easy for them to use the intervention.

3.2 Subject of this study

The subjects in this study were seven experts in learning models, vocational education, language and technology. The experts validated the content of the hybrid learning integrated remote laboratory model design. Suggestions and assessments from experts are used as references in improving the design of the hybrid learning integrated remote laboratory model. To demonstrate the practicality of the hybrid learning integrated-remote laboratory model, the trial was given to three lecturers on embedded systems subjects and 10 students in level five of the computer engineering study programme.

3.3 Instrument and procedure of study

The instrument used was a questionnaire. The questionnaire consisted of content validity questionnaires and practicality questionnaires. The procedure for the development of the hybrid learning integrated remote laboratory model adapted Wademan's model development research design [30], [16].

3.4 Data analysis

The validity of the learning model is measured by using the content validity coefficient proposed by Aiken. Aiken (1985) formulated the Aiken's V formula to calculate the content validity coefficient based on experts' assessments of how well an article represents the construct being measured [31], [32], [33].

4 RESULTS AND DISCUSSION

4.1 Rational development of a hybrid learning integrated with remote laboratory model

Hybrid learning has four learning spaces, namely live synchronous, virtual synchronous, self-paced asynchronous, and collaborative asynchronous [34], as shown in Figure 1. This is reinforced by the opinion of other researchers who stated that the develop hybrid learning is a combination of one or more dimensions [35], [36], namely: (1) Face-to-face learning, face-to-face learning that takes place in the form of classroom learning activities, practical laboratory activities, mentoring or on job training; (2) Synchronous virtual collaboration, a collaborative teaching format that involves interaction between lecturers and students delivered at the same time but in different places; (3) Asynchronous virtual collaboration, is a collaborative teaching format that involves interaction between lecturers and students delivered at different times; (4) Self-pace asynchronous, is an independent learning space where students can determine the time, place and method of learning that suits the students themselves.

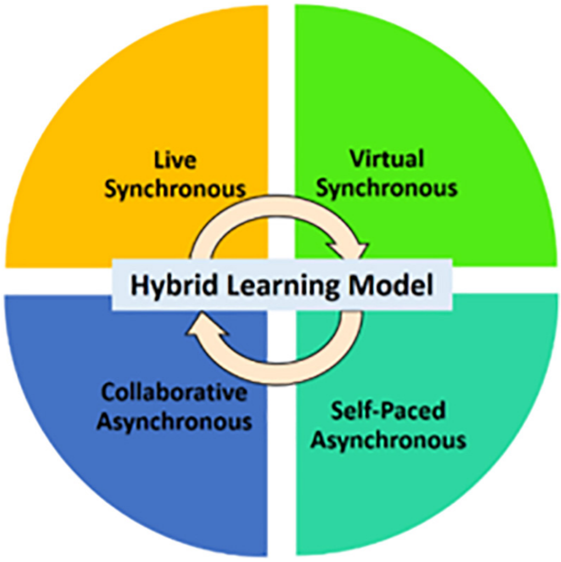

Fig. 1. Four learning spaces of hybrid learning

Based on Figure 1, the planning of a hybrid learning model must provide students with space to study in class accompanied by a lecturer, learn with collaborative strategies, have opportunities to study independently and explore online learning independently. To create an effective online learning space that allows students to collaborate, learn independently and explore learning material, the hybrid learning model must be supported by the use of technology that supports appropriate learning activities. IR 4.0 has the characteristics of technology that is integrated with society and becomes the basis for human life, such as IoT, robotics, quantum computing, biotechnology, 3D printing, vehicle automation, virtual and physical systems collaborating globally [37], [38], [39], [40]. The use of IoT in the implementation of hybrid learning can influence students' active reactions to learning, where students become more interactive and communicative so that learning outcomes increase [32]. Besides that IoT opens up opportunities for students to be able to learn flexibly. The integration of hybrid learning with the technology of the Industrial Revolution 4.0 era is in line with the current educational paradigm, where education is expected to be able to follow the direction of technological change. Students have independent learning spaces with various resources, and lecturers act as facilitators in the learning process, which is not limited to the classroom only.

The hybrid learning integrated remote laboratory model has a differentiated model implementation design, according to Figure 2, to create four dimensions of learning space in embedded system learning.

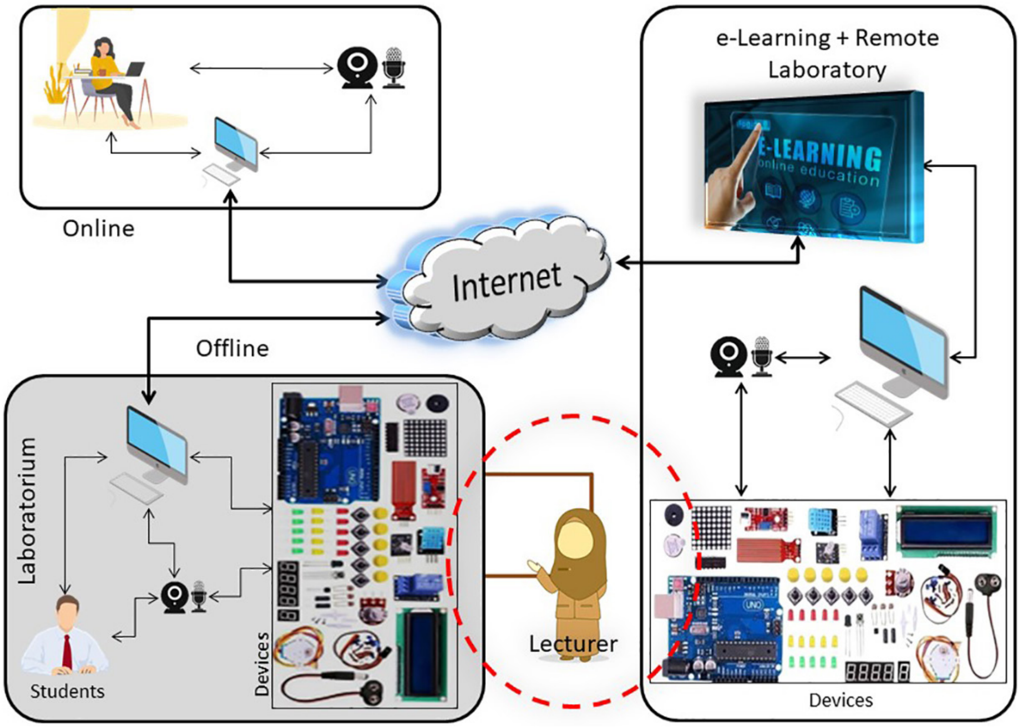

Fig. 2. Design of hybrid learning integrated remote laboratory model

4.2 Rational development of a hybrid learning integrated remote laboratory model with learning theories

The hybrid learning integrated with a remote laboratory model is supported by several learning theories, namely: (1) cognitivism, (2) connectivism, (3) constructivism and (4) behaviorism. The relationship between hybrid learning and cognitivism theories (Jean Piaget, Bruner) is associated with the process through which students acquire, process, and retain information derived from their learning experiences [41]. The connectivism theory (George Siemens) is also highly relevant to hybrid learning systems since hybrid learning incorporates online learning using digital technology. The connectivism theory introduces a new perspective on how learning takes place in the digital space and hybrid learning is designed to deliver learning materials by applying technology while accommodating diverse learning styles and the characteristics of students' learning [42], [43]. Additionally, hybrid learning is also supported by constructivism learning theory (Jean Piaget, Vygotsky and John Dewey), which is a learning theory that contends that cognitive conflict is the first step in the learning process or knowledge acquisition. At the end of the learning process, knowledge will be constructed by students themselves through their interactions with their environment. This cognitive conflict can only be resolved through self-regulation [41]. This theory is in line with hybrid learning, where students construct their knowledge independently through various teaching resources available in e-learning. Besides, hybrid learning follows behaviouristic learning theory (Skinner), where the learning process results in changes in behaviour and where students must act more independently and be responsible in managing their learning process to achieve their learning goals [5], [44].

4.3 Formulation of the syntax of hybrid learning integrated remote laboratory model

The hybrid learning integrated remote laboratory syntax was also developed based on Bloom's education goal classification (Bloom's taxonomy and Bloom's digital taxonomy), as illustrated in Figure 3. In its application, it consists of three phases, namely pre-hybrid class, in-hybrid class and post-hybrid class, with six syntaxes supported by the e-learning integrated remote laboratory application.

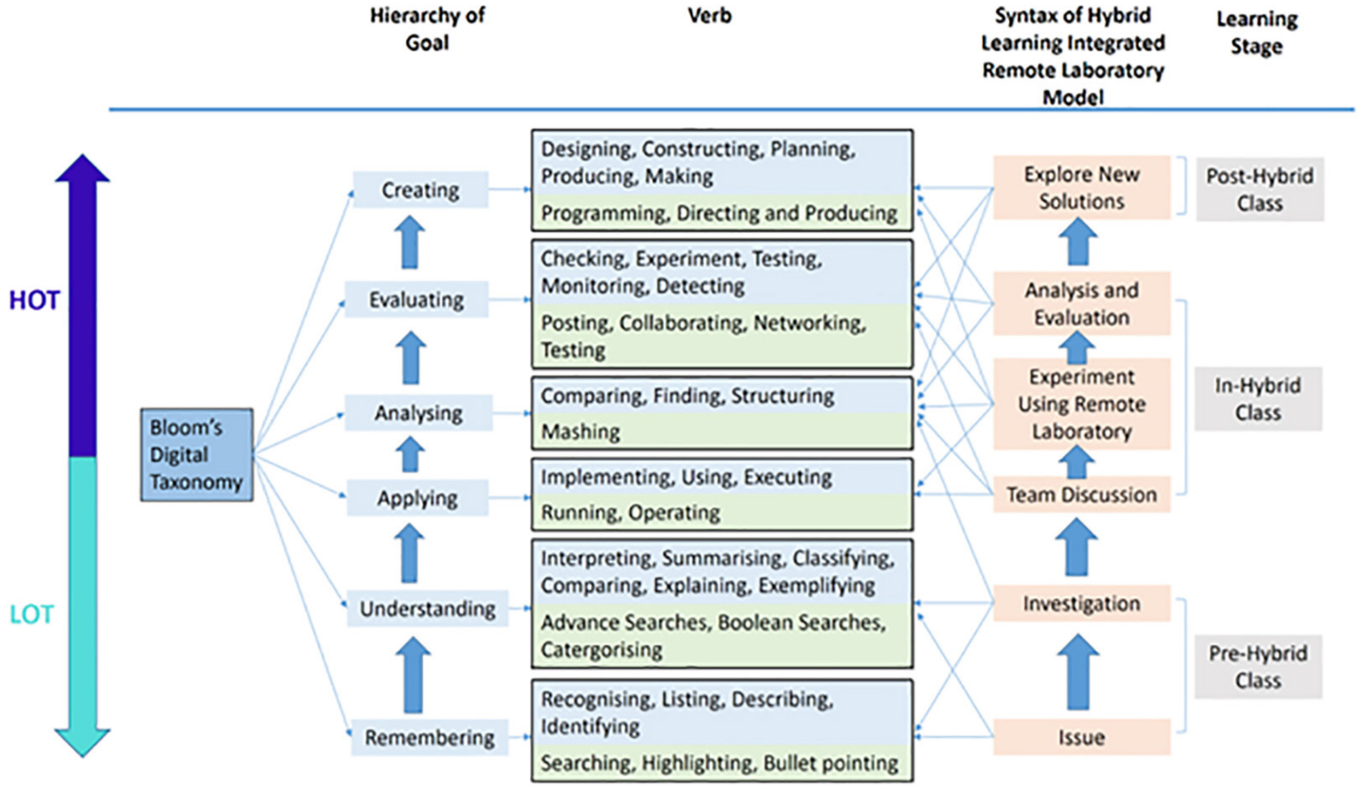

Fig. 3. Hybrid learning-integrated remote laboratory syntax with Bloom's education goal classification rationale

The hybrid learning-integrated remote laboratory syntaxes:

Issue: At this stage, students analyse the issue or phenomenon presented by the lecturer for further investigation. The purpose of this syntax is that the assimilation process occurs from the development of the students' scheme, which is where students gain new knowledge about embedded systems into a scheme or pattern that already exists in their minds. Aside from that, it also provides knowledge and presents issues related to embedded systems that stimulates students' curiosity so that it can motivate students to find more detailed information.

Investigation: Students collect data to support the resulting analysis. The purpose of this syntax is the accommodation process, namely changes to the students' scheme to form a new scheme that is equal to the new stimulus provided in the form of knowledge and experience obtained from the results of investigations carried out by the students.

Team discussion: Students collaborate with other students, whether when they present in class or online, to build a better understanding and find the best solution to the problem that has been presented based on the knowledge they already have, besides that, the lecturer as a mentor guides students in finding the best solution, the purpose of this syntax is to encourage the formation of new ideas from students through grouping students into discussion teams, so that students can interact with fellow students through discussions to determine the best way to solve problems, where according to Vygorsky interaction between students, lecturers and peers is social interaction in the learning process.

Experiment using a remote laboratory: Students apply the solutions that have been discussed in the form of projects through remote laboratories creatively, where the projects are completed in groups either in face-to-face meetings or online meetings. The purpose of this syntax is based on the new knowledge that has been given; students are able to produce many ideas, develop and create new ideas formulated by the students themselves. Apart from that, at this stage there is also a balance process (equilibration) where students combine the new knowledge and experience obtained with the schemes they have.

Analysis and evaluation: Students draw final conclusions about the project; this stage aims to check the measurement of the cognitive, psychomotor and affective abilities that students are expected to have.

Explore new solutions: Independent exploration allows students to develop and create new innovations. The purpose of this syntax is to provide students' opportunity to access practicum media outside of class hours, thereby providing space and time opportunities for students to develop ideas and concepts creatively without being limited by space and time.

The hybrid learning-integrated remote laboratory model syntax has been validated by seven experts in a focus group discussion (FGD). The results of the content validity of the hybrid learning-integrated remote laboratory model consist of: (1) hybrid learning-integrated remote laboratory rationale model; (2) theoretical and empirical support; (3) model characteristics; (4) syntax; (5) social system; (6) reaction principle; (7) support system; and (8) instructional impact and accompanist impact. These had Aiken V scores of 0.88, 0.87, 0.88, 0.89, 0.88, 0.87, 0.87 and 0.86, as shown in Figure 4. The final Aiken V value was 0.87, so the content validity of the hybrid learning-integrated remote laboratory model was declared valid.

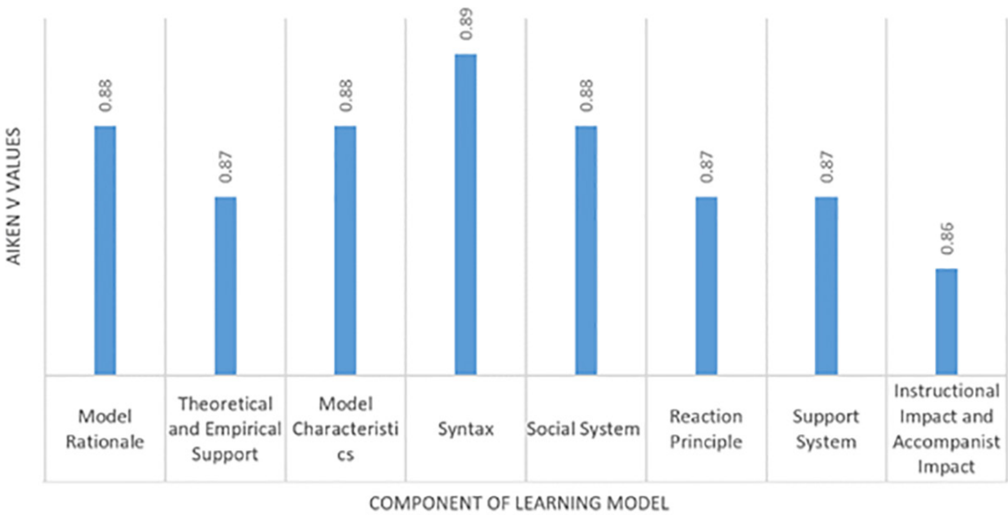

Fig. 4. Result of the hybrid learning-integrated remote laboratory model quality assessment

Social systems: In the learning process in the hybrid learning model integrated with a remote laboratory, there is active reciprocal interaction between the lecturer and students as well as interactions between fellow students. Interaction between lecturer and students occurs both outside and inside the classroom. This interaction starts with pre-hybrid-class activities, where the lecturer motivates and stimulates students to develope the knowledge they have. This interaction process continues in-class and post-hybrid. Students' collaboration occurs well in face-to-face or online meetings when conducting group discussions and completing projects. The social system expected from the use of a hybrid learning model integrated with a remote laboratory are students who are active in taking part in learning, discussing in groups, asking questions and answering the lecturer, collaborating in completing projects, along with training students to be disciplined, respect other students' opinions and have the courage to express their own opinions or ideas.

Reaction principle: At each learning phase, there is active interaction in the form of providing motivation by the lecturer, discussion forums online, and a remote laboratory which is a forum for online collaboration in working on and completing projects as well as a means for the lecturer to monitor the completion of student group projects. The lecturer's role is as a facilitator in motivating, directing and guiding students in building a spirit of independent learning through online learning.

Support system: The support system for implementing the development of this hybrid learning model is a remote laboratory, learning modules, online teaching materials in the form of PowerPoint and video presentations, questions and assessment sheets.

Instructional impact and accompanist impact: The instructional impact that students are expected to gain is in the form of (a) being able to analyse problems, (b) designing stages of problem solving, and (c) creating projects that support problem solving. Meanwhile, for the accompanying impact, students can learn flexibly because there is a learning dimension that opens up space for discussion, collaboration and flexible independent practicum, providing the impact of critical, creative and innovative thinking.

Qualitative data analysis supported the statistical test results; the expert overview of the qualitative data from the FGD is shown in Table 1.

Table 1. Qualitative data for the hybrid learning integrated remote laboratory model

Component	Qualitative Data for the Hybrid Learning Integrated Remote Laboratory Model
Hybrid learning integrated remote laboratory model rationale	The experts stated: "Hybrid learning integrated remote laboratory model rationale has compatibility between the reasons for creating the educational system and the current need for approval for the creation of this model is valid."
Theoretical and empirical support	The experts stated: "There is a compatibility between the Hybrid learning integrated remote laboratory model with learning theory, Bloom's taxonomy and other empirical support."
The characteristics of Hybrid learning integrated remote laboratory model	The experts stated: "It contains the specifics of the model with the basic characteristics of the model based on theoretical studies and it has innovations in learning so that it is declared valid."
Hybrid learning integrated remote laboratory syntax	The experts stated: "There is a clear sequence of activities in each phase in achieving the expected learning outcomes so that the syntax developed is valid."
Social system	The experts stated: "The social system that visualizes the role of students and lecturers, explain the form of activity between of them, interaction and collaboration between students in live synchronous, virtual synchronous, self-paced asynchronous, and collaborative asynchronous."
Reaction principle	The experts stated: "Reaction related to how the lecturers notices and treats the students has been specified and it is valid."
Support system	The experts stated: "The model book explains logically about the hybrid learning integrated remote laboratory support system which comprising of tools of study and resources of study in the application of this model."
Instructional impact and accompanist impact	The experts stated: "The instructional impact in the form of achieving learning outcomes and the accompanying impact of the hybrid learning integrated remote laboratory model as a result of the environment created by the model is explained logically in the model book."

The FGD findings showed that the hybrid learning integrated remote laboratory model is valid in content. The model has several traits, namely fulfilling the needs because it provides flexible learning space. This model is integrated with a remote laboratory so that it provides students with space to use practical tools in embedded systems online courses. The learning process is based on problems in embedded systems subjects, collaborative, and contains learning elements in IR4.0. This model also has a robust theoretical and empirical groundwork and has steadiness between model components so that it can be used in embedded systems learning.

4.4 Practicality test results

Practicality testing has been carried out on teachers and students through practicality testing of learning models. The hybrid learning integrated remote laboratory practicality test was carried out by lecturers of embedded systems subjects and students.

Table 2. Practicality analysis results of hybrid learning integrated remote laboratory model

Respondent	Percentage (%)	Category
Lecturers	88.44	Very practical
Students	87.89	Very practical
Average	88.16	Very practical

Based on Table 2, the practicality of the hybrid learning integrated remote laboratory model is based on the responses of lecturers and students through questionnaires. The average percentage of the assessments from lecturers was 88.44% and from students was 87.89%; the overall average result is 88.16% in the very practical category. These results indicate that the very practical category developed can make it easier for students to understand the embedded system concept and practicum.

The application of the hybrid learning-integrated remote laboratory model allows the embedded system's practical learning process to be carried out flexibly in terms of space and time. This is in line with a previous study that stated that hybrid learning allows learning to occur anywhere, anytime, anything and anyone [45]. Students have flexibility and freedom to control their learning [46], so hybrid learning is a learning model with a student-centred learning approach [13]. The social environment system of hybrid learning integrated in to a remote laboratory creates active interaction and collaboration among students. This is in line with studies that provide positive student's satisfaction in collaborative learning regarding the application of hybrid learning [47], [48]. Hybrid learning has many positive impacts on the development of education; however, there are still several challenges in the design and development of hybrid learning in the future related to learning activity design that is appropriate to the subject, infrastructure and ICT trainings for teachers and students to enhance their skills with technology.

5 CONCLUSION

The feasibility analysis of the hybrid learning integrated remote laboratory model is supported by cognitivism, connectivism, constructivism and behaviourism theories. The hybrid learning-integrated remote laboratory model consists of six syntaxes. There are: 1) issues in embedded systems 2) investigations; 3) team discussions to solve problems; 4) experiments using remote laboratories; 5) analysis and evaluation; and 6) exploring new solutions. The hybrid learning integrated remote laboratory syntax is supported by Bloom's taxonomy and Bloom's digital taxonomy in the levels of remembering, understanding, applying, analyzing, evaluating and creating. This study also created a hybrid learning integrated remote laboratory model that has characteristics formulated in accordance with the characteristics of flexible learning, namely flexibility in time management, flexibility in lecturer communication with students and fellow students, and flexibility in content where students can learn the content that they want whenever and wherever they want to learn. The result shows that the hybrid learning integrated remote laboratory model has high validity and is very practical. Further study could be conducted to continue testing the effectiveness of the hybrid learning-integrated remote laboratory model.

6 ACKNOWLEDGMENTS

The authors thank Universitas Negeri Pandang and Universitas Putra Indonesia YPTK Pandang for supporting this study.

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