Full research paper

EVALUATION OF VIRTUAL WORKSPACE LABORATORY: CLOUD COMMUNICATION AND COLLABORATIVE WORK ON PROJECT-BASED LABORATORY

Juli Firmansyah[1]✉
Andi Suhandi[2]
Agus Setiawan[2]
Anna Permanasari[2]

[1]Physics Education Department, Universitas Serambi Mekkahc, Indonesia

[2]Science Education Department, School of Postgraduate, Universitas Pendidikan Indonesia, Bandung, Indonesia

✉ juli.firmansyah@serambimekkah.ac.id

ABSTRACT

This study evaluated the success or failure of using Virtual Workspace (VW) in a project-based physics laboratory. This study uses a qualitative approach with 4E evaluation methods: educational effectiveness, ease of use, involvement, and environment. Data were collected through a questionnaire to evaluate the implementation and practical functions of the VW CCCW. In addition, data were also collected using interview techniques to find out how the perceptions of students and instructors or lecturers during project-based physics practicums apply VW CCCW. The sample of this study consisted of 126 respondents consisting of 104 prospective physics teacher students, 12 lecturers of basic physics courses, and ten laboratory instructors representing public and private teacher education universities in Aceh. The evaluation findings show that VW has been successfully implemented and tested. The use of virtual workspaces as a tool in practical work is very effective in training 4C skills. Therefore, as an implication in the 4.0 revolution era, virtual workspaces in practicum can be a new way to work collaboratively with task management, creative action plans, communication and problem solving, critical thinking and completing projects, and practicum performance evaluation and assessment.

KEYWORDS

Cloud communication, collaborative work, project-based laboratory, virtual workspace

HOW TO CITE

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Highlights

- *Virtual workspace effectively used in research laboratory activities and project management in Universities.*
- *Proposed Practicum Model for the higher education system that will permanently implement distance learning with technology integrated.*
- *The implications of using Virtual Workspace in laboratory activities (pre-lab, lab, and post-lab) have an impact on 4C skills and answer the challenges of the 21st-century.*

INTRODUCTION

The use of Information and Communication Technology (ICT) in practicum has provided many changes in prospective physics teacher students' success in understanding concepts and forming attitudes. However, ICT integration at every practicum stage still faces serious challenges. The type of ICT used significantly impacts prospective student teachers' skills in the era of the industrial revolution 4.0 (IR4) in the 21st-century (Liesa et al. 2020). The term IR4 comes from the German government project to promote computerized manufacturing. The era of the industrial revolution is also called the digital revolution and the era of disruption (Sima et al. 2020), where fundamental changes occur due to technological changes in every aspect of people's lives. The industrial revolution began with a) Industrial Revolution 1.0 occurred in the 18th century after the invention of the steam engine, thus allowing goods to be mass-produced, b) The Industrial Revolution 2.0 occurred around the 19–20 century through the use of electric power in machines which made production costs cheap, c) The Industrial Revolution 3.0 occurred around the 1970s through the use of computers in various aspects of factory production for the needs of people's lives, and d) The Industrial Revolution 4.0 occurred around 2010 through artificial intelligence and the internet of things as the backbone of movement and connectivity between humans and machines.

21st-century skills in the 4.0 industrial revolution era are considered capable of strengthening social and intellectual skills, critical thinking and problem-solving skills, creative thinking skills, communication skills, and collaboration skills, commonly abbreviated as 4C Skills (Stehle and Peters, 2019). Operationally, the 4C Skills can be discussed in four aspects: First, ways of thinking, including creating, innovating, being critical, solving problems, making decisions, and proactive learning. Second, how to work, including communicating, collaborating, and working in teams. Third, how to live as a global and local citizen simultaneously; fourth, tools for developing 21st-century skills, namely information technology, digital networks, and literacy.

Previous research has used ICT in hands-on practicum and virtual practicum (Banerjee, Murthy and Iyer, 2015), which shows that ICT is effectively used in practicum as a tool for visualization (Hillmayr et al., 2020) and easy access to experimental data (Wang and Tahir, 2020). However, ICT in practicum has only been used in data processing activities (Rogers and Finlayson, 2004). The pre-practicum and post-practicum stages, including practicum performance assessment activities, are carried out manually or without using ICT (Mabunda, 2013). Several strategies can be done to improve the quality of practicum using ICT (Gogoulou and Grigoriadou, 2021), one of which is to consider using the Workspace to facilitate collaboration and communication skills during the practicum (Lima and Siebra, 2021; Cheung and Vogel, 2013; Dávideková and Hvorecký, 2017) and to practice critical and creative thinking skills (Stehle and Peters, 2019).

Based on previous research, the use of ICT in practicum is suggested to be broader, starting from the pre-practicum, practicum, post-practicum, and assessment stages (Trepulė et al. 2021). One way to apply ICT widely in practicum is to use virtual Practicum Workspace. The use of workspaces in practicum has never been done before and can be an innovation value in the 21st-century practicum. An illustration in figure 1 shows the application of a virtual workspace extensively in the practicum.

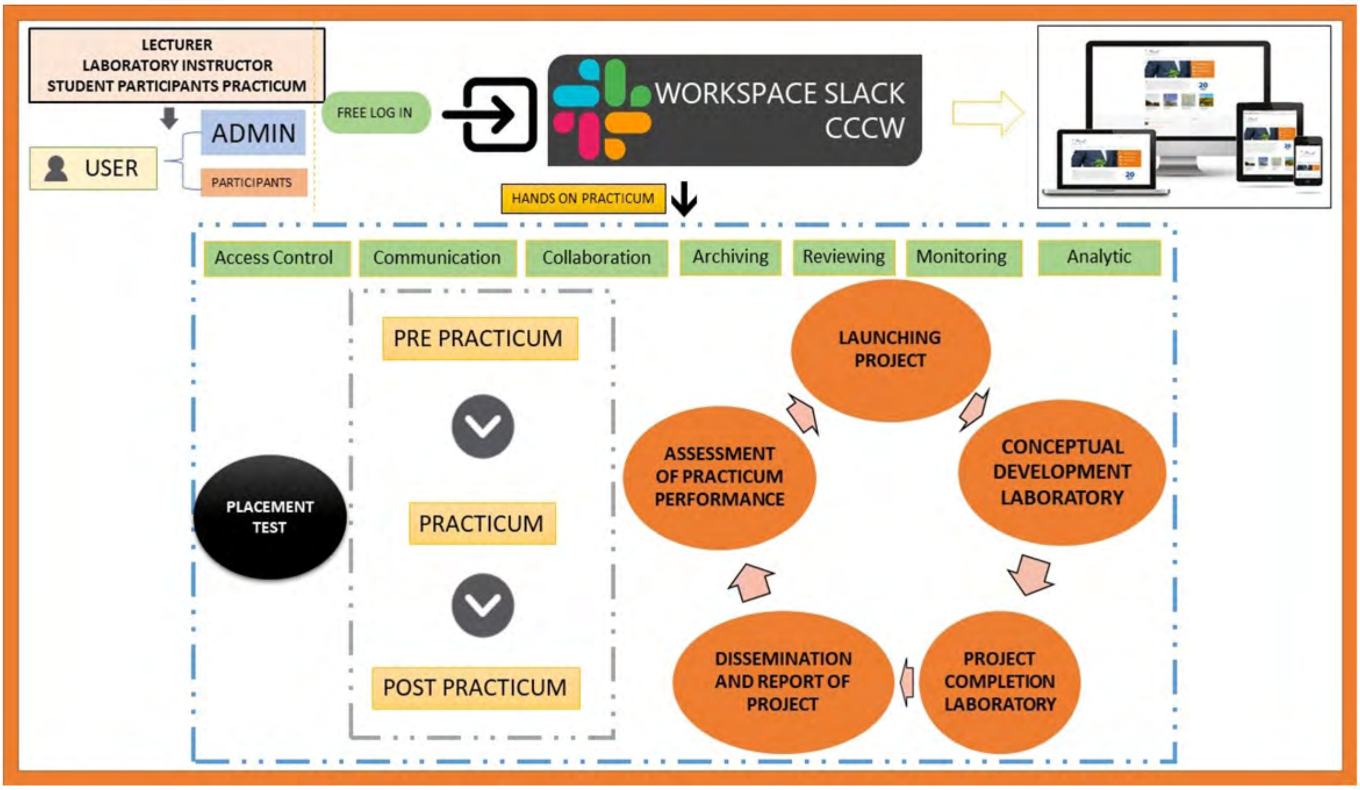

Figure 1: CCCW Workspace Integration Model in Project-Based Practicum, 2020

Workspace-assisted practicums can foster powerful learning and practical experiences by allowing virtual teams to engage in synchronous and asynchronous discussions anytime, anywhere and are very effective at saving time (Sikkel, Gommer and Van Der Veen, 2002; Bell and Kozlowski, 2002); this is very difficult to achieve in real laboratories (Collis, Peters and Pals, 2000; Hew and Cheung, 2012). In conducting workspace-assisted practicum, communication activities and collaborative practices must be encouraged to develop by adding projects that involve the team (Bond-Barnard, Fletcher and Steyn, 2018), by staying in touch with each other (exchange and store data) in the cloud, and collaborative work in the workspace (Darmaji et al. 2019). One of the workspaces suitable for project-based practicum is the Slack workspace.

Therefore, this study investigates the possible success or failure of using Slack workspace in a project-based physics practicum. Slack is a cloud-based digital workspace and information management system used to manage productivity and increase group work efficiency (Johnson, 2018). Using Slack allows students to communicate, collaborate with instructors and peers, discuss in their respective groups, save documents, and download videos (Rombaut, 2016). Slack has 80+ integrations, such as google drive and Trello, so that not only is it easy to share documents and project planning, it also works together in collaboration and cloud-based communication quickly. It shares essential documents seamlessly so that in this case, Slack can also refer to as cloud communication and collaborative work (CCCW).

Consequently, it is necessary to organize a study to be structured to answer the following open questions. How can a virtual workspace (VW) effectively and efficiently support project-based physics practicum activities? How to know that the features in CCCW are functioning effectively in supporting the implementation of project-based physics practicum? Thus, the main objective of this study was to evaluate the success or failure of using Slack's Virtual Workspace (VW) in a project-based physics laboratory.

Basic Support to Cloud Communication and Collaborative Work

Slack, or it can be referred to as CCCW, is a virtual workspace that can be accessed via a web browser and smartphone application with access restrictions for participants who have registered as participants in the workspace (Johnson, 2018). The primary function of VW CCCW is for more effective project management with easy document storage so that participants in the workspace can have access to collaborative work in groups that do not meet face-to-face often.

VW CCCW Slack makes it easy for users to collaborate in cloud-based work because it is connected to Google Drive through all types of documents such as pdf, office, video, audio, and jpg. During collaboration in VW CCCW, users can communicate directly (direct messages) with fellow users and collaborate with instructors or lecturers even through conference connections with zoom meeting links.

Using the Virtual Workspace CCCW

VW CCCW is applied in project-based physics practicum activities to manage project practicum products. As practicum participants who have been invited to VW CCCW, they fill out their biodata and upload photos on the available channels. After that, students take a pre-test response through the link that has been prepared in the discussion column. Based on the pre-test responses, students occupy the practicum group with an even distribution in each group. In the next stage, students can read project-based practicum modules and videos according to the project needs to be provided in the workspace. Students can download attachments in the form of student worksheets in practicum and projects. Project management begins after strengthening the physics concept in the form of practicum has succeeded in finding the physics concepts involved in the project to be undertaken. In the end, students re-upload their practicum and project performance reports to the available channel. CCCW Workspace Slack has many features that support collaborative work between practicum participants. The interface is easy to navigate. There are hundreds of things you can do quickly on Slack, including embedding messages, sending notifications to everyone, conducting public group chats, private group chats, or direct messages (Rombaut, 2016).

The interface of the virtual practicum workspace which has several channels is shown in figure 2. Slack can be meaningful through the communication feature; prospective physics teacher students can communicate with instructors and other members.

VW CCCW facilitates students to discuss and share information during practicum. Sending chat messages and discussions can take place with specific groups and in general. The direct message feature helps students communicate, discuss, send files (pdf, office, jpg, mp4, etc.). VW CCCW makes it easy for students to save and collect various files, files can be in the form of practicum guides, project modules, practicum and project assessment sheets, practicum performance attachments, or videos and animations related to project work.

VW CCCW facilitates participant collaborative work during project-based practicum. Participants and instructors or lecturers can provide responses and assessments of practicum participants' work sent or stored in the Slack workspace. Instructors or Lecturers can monitor project-based practicum activities through the Slack workspace. Because VW CCCW has limited access to passwords, VW CCCW admins can control access so that document and data access can be restricted to specific subgroups and cannot be accessed by the public at large.

Participants' activities in the VW CCCW can be recorded and monitored with the analytic feature to review the activities of members/practicum participants. In the Analytics feature, the admins can check practicum participants' activities in VW CCCW. They are starting daily to weekly activity information on each channel to evaluate who reads messages or does not read statements. With this feature, the admin, in this case, is a lecturer who can assess practicum participants' communication and collaboration skills.

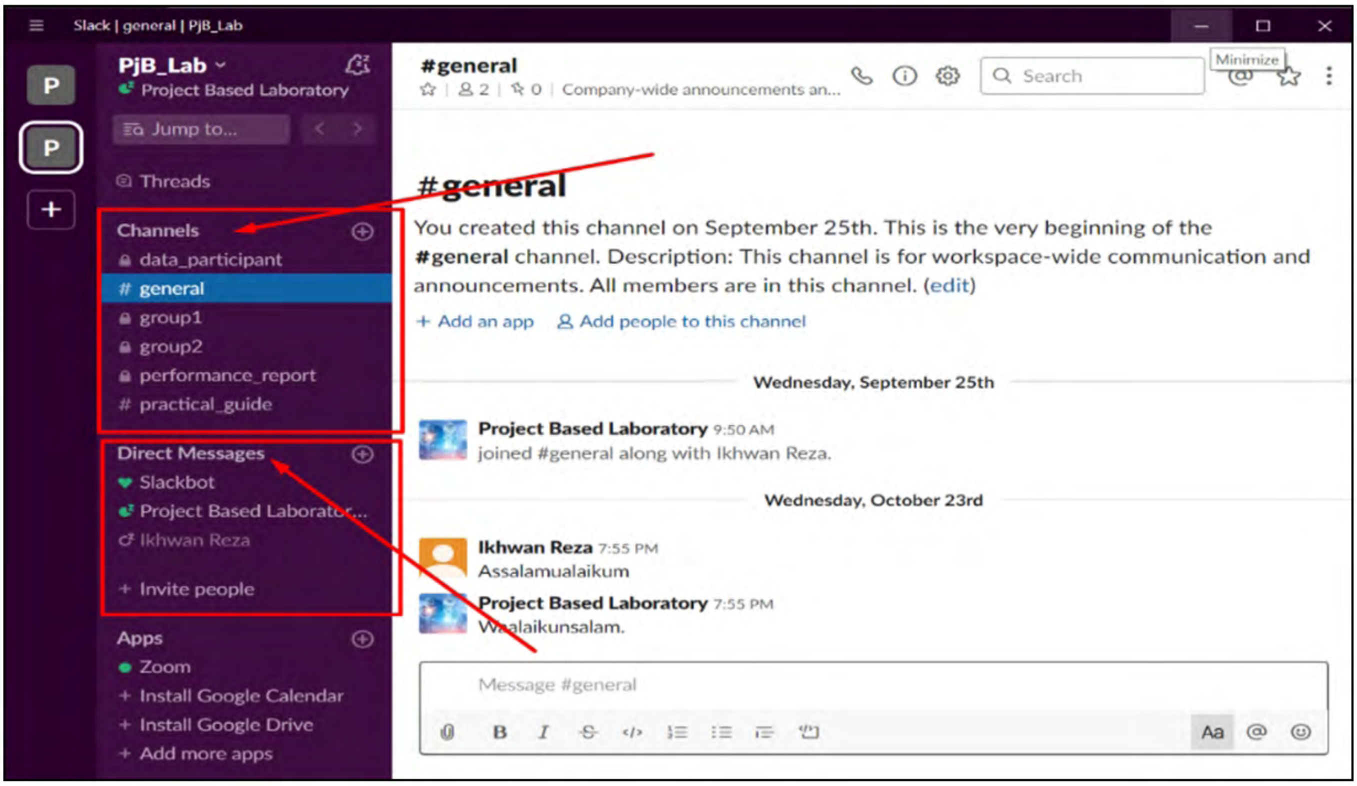

Figure 2: Virtual practicum workspace interface, 2019–2020 (Slack.com, 2020)

RESEARCH METHOD

The evaluation studies apply mixed methods, qualitative and quantitative methods used in this study. This method is used to investigate possible reasons for the success or failure of using workspaces CCCW in higher education. The success of implementing VW CCCW is then evaluated by four variables (Collis, Peters and Pals, 2000), namely Educational effectiveness, Ease of use, Engagement, and Environment (4E Models) through questionnaires and interviews.

The 4E Models are used to predict the likelihood of using workspace during practicum PJB-Lab. In the 4E model developed by (Collis, Peters and Pals, 2001), several variables to predict the success of implementing ICT applications in the educational environment are grouped into four general factors, namely Educational effectiveness, Ease of use, Engagement, and Environmental variables (related to organizational, social-cultural and technological factors). Table 1 explains the description of the four variables of the 4E model within the scope of using the VW CCCW during project-based practicum.

Aspect	Description
Educational effectiveness (E1)	• Relevance for practical tasks and problem-solving in group work. For example, bridging the distance between group members or overcoming the lack of opportunities for collaboration and communication. • One gain relative advantages from using VW CCCW compared to other modes can influence the users' perception in accomplishing practical tasks.
Ease of use (E2)	• It includes easy-to-learn tools, a friendly user interface, and efficient tasks that conform to typical work habits. • Ease of use also depends on the user's computer skills, previous experience with similar tools, easy access to network computers, availability of support (Google Drive, Trello, zoom, dan SurveyMonkey), and the costs associated with using telematics services.
Engagement (E3)	• Common willing to invest additional effort in starting and using telematics services for education. • Higher satisfaction with successful use of VW CCCW. On the other hand, a lack of confidence in one's personal skills to handle ICT results in negative engagement.
Environment (E4)	• Environmental factors outside the course include institutional, socio-cultural, and technological factors such as individual and institutional attitudes towards educational technology innovations; readiness of institutions to offer ICT services and support in an accessible, reliable and affordable manner.

Table 1: Description 4E Model Variabel, 2020 (Sikkel, Gommer and Van Der Veen, 2002)

There are several implications of using the 4E evaluation model of the CCCW WS as a 21st-century practical innovation. First, the descriptive implications, namely the results of this evaluation, can be used as new knowledge and insights on how individuals or practicum workgroups respond to the application of ICT in practicum. Second, authoritarian implications, the 4E model can identify essential parts of ICT tools that can help and solve learning and practicum problems. Third, various positive and negative responses can be used as the basis for further development and research on ICT application in science practicum. Finally, the 4E model shows the success of 21st-century science practicum innovations. This follows the scientific theory that science practicum can not be replaced by ICT without considering the characteristics of the practicum topic.

This study was conducted at two types of universities, namely public and private universities, involving 126 respondents from lecturers, laboratory instructors, and prospective physics teacher students. The explanation for the selection of the two types of universities is that the geographical role of the two universities in coastal areas provides a history almost the same as the two types of universities as teacher education institutions.

Participants

Participants involved in the research have a background in using ICT in learning; everyone involved in education must be trained to operate ICT in distance learning. The research sample consisted of students who had completed fundamental physics I courses, practicum instructors, and lecturers who taught basic physics practicum courses from two kinds of campuses in Aceh, Indonesia. The sample consisted of 63 representatives from private universities (PU), while 63 were from State University (SU). Table 2 shows the research sample.

Sample	Institution	Number of Samples	Male	Female
Lecturer	PU	6	4	2
	SU	6	3	3
Lab Instructor	PU	5	2	3
	SU	5	2	3
Students	PU	52	25	27
	SU	52	23	29
Total		126	59	67

Table 2: Research Samples, 2020

Data Collection

The study data were collected by questionnaire to evaluate the implementation of CCCW and were administered and sent to lecturers, laboratory instructors, and students after the practicum was completed. The questionnaire was given via a google form link which can be accessed through the CCCW WS by each practicum participant. Researchers triangulated data through open interviews with lecturers, lab instructors, and students participating in the practicum. Students are determined randomly from each working group. All data collection processes have obtained permission from institutions, respondents, and parents of students. They have signed the consent form for the publication of research data. However, the name or initials of the institution remain confidential for ethical reasons.

Questionnaire

The questionnaire of the 4E model was given to determine the extent to which VW CCCW was successfully used and supported project-based practicum activities. Scaled question items were used to measure the 4E aspect with each scale indicating a scale: 1 = I completely disagree – 2 = I usually disagree – 3 = I cannot say – 4 = I usually agree – 5 = I strongly agree. The 4E model evaluation questionnaire was adopted from the instrument developed by Collis, Peters and Pals (2001).

Cross comparison case, some of the VW Slack's functionalities on practicums activity were included in the other examined questionnaire: discussion (chat), archiving, collaboration, reviewing, monitoring, access control, and analytics. Evaluation of the function of the VW CCCW feature using three types of responses. The first response is successful (+), representing the feature successfully used and supporting the practicum. Second, the Neutral response (+/-) describes influential but not crucial features supporting the practicum. Finally, the negative response (-), which represents the feature, does not support the practicum or has not been used successfully.

Interviews

Open questions in the interview were given to investigate how practicum participants were perceived to use VW CCCW in project-based physics practicum. Lecturers, laboratory instructors, and some practicum participants (3–4 from each group) were invited to participate in an interview after the experiment to understand their perceptions and opinions about the use of VW CCCW in practicum.

Interview Questions for Laboratory Lecturers and Instructors: (1) How do you understand VW CCCW integration for a project-based physics lab? (2). After integrating the project-based practicum stage into VW CCCW, do you have a preference for VW CCCW or traditional hands-on practicum without ICT assistance? (3). Among these preferences, which one can help practicum participants better in practicum performance?

Interview questions for practicum participants are (1). How did you feel during the VW CCCW project-based physics practicum? (2). What did you do in VW CCCW when starting your physics lab project? Did you follow the instructions in VW CCCW step by step, or did you try it yourself first? (3). Does studying practicum guidelines through VW CCCW help you complete a science project?

RESULTS

The data that has been collected are then analyzed and presented following the stages of data collection. The reliability test used to reflect the scale's internal consistency based on the 4E model cluster directly in the questionnaire used in this study is presented in table 3. As shown in table 3, the four measures of educational effectiveness, ease of use, personal engagement, and environmental are above the acceptable level (0.600 and above). In other words, this questionnaire can be said to be reliable as a research data collection tool.

In figure 3, the person's mean score measure shows the number 0.99 or greater than 0.00. This value indicates that the tendency of the respondent's ability is greater than the level of difficulty of the questionnaire.

Instrument Scales (42 item)	Alpha Score
Educational Effectiveness	0.870
Ease of Use	0.813
Personal Engagement	0.806
Environmental	0.793

Table 3: Instrumen Scale Reliabilities from 4E Model Questionnaire, 2020

Cronbach's Alpha value (KR-20) is the interaction between respondents and the item as a whole. The alpha value is 0.82. This shows that the reliability of the test is generally satisfactory. The value of the person and item reliability is 0.74. This indicates that the consistency of the respondents' answers and the quality of the questionnaire items in the instrument's reliability aspect are good.

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-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT     |
|          SCORE      COUNT     MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN     116.6      42.0         .99     .58                                 |
|  SEM        .6        .0         .16     .04                                 |
| P.SD       5.0        .0        1.38     .36                                 |
| S.SD       5.0        .0        1.39     .36                                 |
| MAX.     125.0      42.0        4.56    1.83                                 |
| MIN.     107.0      42.0       -1.01     .41                                 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .70 TRUE SD    1.19  SEPARATION  3.68  Person RELIABILITY  .74 |
|MODEL RMSE    .68 TRUE SD    1.20  SEPARATION  3.75  Person RELIABILITY  .75 |
| S.E. OF Person MEAN = .16                                                   |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .94
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .82  SEM = 2.13
 |
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT     |
|          SCORE      COUNT     MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN     349.7     104.0         .00     .28       .99   -.12   1.04    .02 |
|  SEM       1.5        .0         .11     .00       .03    .28    .08    .34 |
| P.SD       7.5        .0         .55     .01       .16   1.36    .40   1.65 |
| S.SD       7.7        .0         .56     .01       .17   1.39    .41   1.68 |
| MAX.     357.0     104.0         .98     .29      1.31   2.56   1.98   3.72 |
| MIN.     336.0     104.0        -.56     .26       .79  -1.84    .68  -1.47 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .29 TRUE SD     .46  SEPARATION  3.61  Item   RELIABILITY  .72 |
|MODEL RMSE    .28 TRUE SD     .47  SEPARATION  3.68  Item   RELIABILITY  .74 |
| S.E. OF Item MEAN = .11                                                     |
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Figure 3: Respondent Analysis and Item Reliability, 2020

The graph in figure 4 shows a questionnaire of suitable and reliable items used to determine the moderate ability level. The higher the peak of the information graph that can be achieved, the higher the measurement reliability value of the 4E model questionnaire.

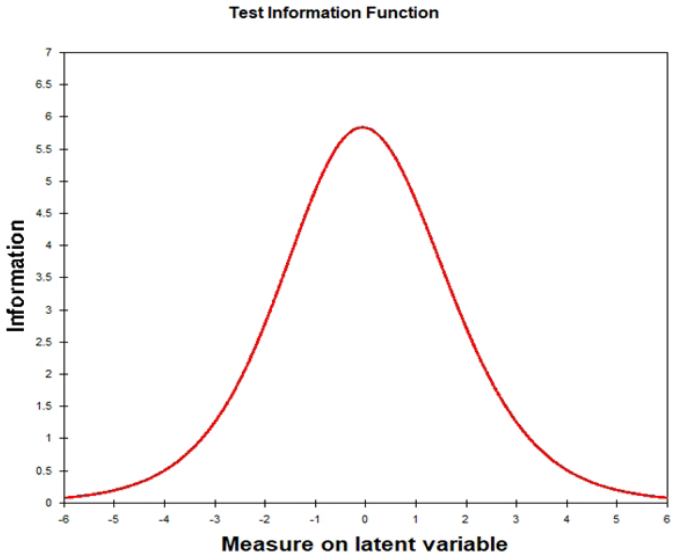

Figure 4: Test Information Function, 2020

Practical Functions

The reliability test of the alpha model was also used to reflect the internal consistency of the questionnaire scale for the success of the CCCW feature function presented in Figure 5. Alpha scores were above the acceptable level (0.600 and above). In other words, this questionnaire can be said to be reliable. The questionnaire results on the success of the CCCW WS feature function in the project-based physics lab are described in table 4.

The person's score means measure shows the number 0.94 or greater than 0.00. This value indicates that the tendency of the respondent's ability is greater than the level of difficulty of the questionnaire.

Cronbach's Alpha value (KR-20) is the interaction between respondents and the item as a whole. The alpha value is 0.74. This shows that the reliability of the test is generally satisfactory. The value of the person and item reliability is 0.74. This indicates that the consistency of the respondents' answers and the quality of the questionnaire items in the instrument's reliability aspect are quite good.

```
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE    S.E.       MNSQ  ZSTD   MNSQ  ZSTD  |
|-----------------------------------------------------------------------------|
| MEAN      25.0      13.0        2.30    1.61                                 |
|  SEM        .2        .0         .21     .05                                 |
| P.SD       1.6        .0        1.79     .40                                 |
| S.SD       1.6        .0        1.80     .41                                 |
| MAX.      26.0      13.0        3.46    1.89                                 |
| MIN.      21.0      13.0       -2.11     .95                                 |
|-----------------------------------------------------------------------------|
| REAL RMSE   1.69 TRUE SD     .59  SEPARATION   3.35  PERSON RELIABILITY .71 |
|MODEL RMSE   1.66 TRUE SD     .67  SEPARATION   3.40  PERSON RELIABILITY .74 |
| S.E. OF PERSON MEAN = .21                                                    |
-------------------------------------------------------------------------------
PERSON RAW SCORE-TO-MEASURE CORRELATION = 1.00
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .74  SEM = .82

-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE    S.E.       MNSQ  ZSTD   MNSQ  ZSTD  |
|-----------------------------------------------------------------------------|
| MEAN     349.2     104.0         .00     .51        .94  -.36   1.29   .05  |
|  SEM       2.4        .0         .56     .02        .15   .69    .41   .77  |
| P.SD       5.5        .0        1.26     .04        .34  1.55    .91  1.73  |
| S.SD       6.0        .0        1.38     .04        .38  1.70   1.00  1.89  |
| MAX.     337.0     104.0        1.46     .58       1.46  1.95   2.72  2.64  |
| MIN.     345.0     104.0       -2.10     .47        .49 -2.56    .41 -2.17  |
|-----------------------------------------------------------------------------|
| REAL RMSE    .54 TRUE SD    1.14  SEPARATION  2.11  ITEM   RELIABILITY  .72 |
|MODEL RMSE    .51 TRUE SD    1.16  SEPARATION  2.27  ITEM   RELIABILITY  .74 |
| S.E. OF ITEM MEAN = .56                                                      |
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Figure 5: questionnaire scale for the success of the CCCW feature function

Some features of VW CCCW are considered not to support the overall practicum. At least 3% of students agree that the archiving feature is not very useful during the practicum and 13% agree that the collaboration and monitoring features of VW CCCW are not so crucial in the success of the project-based physics practicum.

The use of the CCCW Slack has been successfully implemented during the practicum with the support of valuable features such as discussion or chat features (100%), archiving (97%), collaboration (87.50%), reviewing (100%), monitoring (86.54%), access control (100%) and analytics (100%). This finding proves that all features are successfully operated and support project-based physics practicum, as shown in Figure 5.

Functional	Statement	*N* = 104			Percentage (%)		
		+	+/-	-			
Discussion	Using the CCCW helps you exchange information quickly and easily during the practicum	104	0	0	100	0	0
Archiving	The CCCW makes it easy to exchange data and files to discuss practicum issues	97	7	0	93	7	0
	The CCCW helps you access and upload data such as document and video files during practicum	100	4	0	96	4	0
	You can save all files in your CCCW account to your google drive	104	0	0	100	0	0
	CCCW makes it easy to follow practicum performance evaluations	104	0	0	100	0	0
Collaboration	CCCW helps you communicate with instructors and lecturers	104	0	0	100	0	0
	CCCW makes it easy for you to communicate to develop project plans and create practicum reports	87	17	0	84	16	0
	The CCCW makes it easy to discuss practicum issues found during practicum	85	19	0	82	18	0
	Makes it easy for your collaboration work during practicum	88	16	0	85	15	0
Reviewing	CCCW makes it easy to review the materials and results of discussions that have been conducted	104	0	0	100	0	0
Monitoring	You can view your peers' activities while using the CCCW in practicum	90	14	0	87	13	0
Control Access	The CCCW feature has certain access restrictions, so it requires permission from the admin to perform activities	104	0	0	100	0	0
Analytic	Analytic features help evaluate the involvement of practicum participants during practicum	104	0	0	100	0	0

Table 4: CCCW Feature Function, 2020

Based on the evaluation results using the 4E model with a scale range of 1 (strongly disagree) - 5 (strongly agree), the implementation of the CCCW workspace is considered effective in supporting the practicum process (4.69), ease of access, and availability of facilities and networks (4.69). In addition, it was found that students were interested in using VW CCCW in physics practicum (4.67). The application of VW CCCW in project-based physics practicum has institutional support and follows the concept of technological development (4.53).

Qualitative Data Results from Interviews

The feedback from lecturer and laboratory instructor interviews was collected and summarized into three points. First, VW CCCW helps practicum participants develop knowledge and find concepts with project completion. Practicum participants can read practical guides and concept summaries presented in VW. Before practicum participants collaborate directly, students communicate with each other to explore physics concepts that will be applied in the project by investigating the relationship of quantities and developing physics concepts as a practical product. During the work of practicum products, collaboration within CCCW and outside CCCW trains the critical and creative thinking skills of practicum participants.

Second, the attitudes of the practicum participants towards physics became better after CCCW was used during the project-based practicum; this can be seen at least from their motivation and concentration that were better than usual during the practicum. The participants have easy access to various types of data by using text, images, animation, and video, google drive, quick quiz, zoom, Trello, and accessible documentation of realistic data with tidy filing helps the participants link with other applications. These types of data and their use motivate practicum members to be passionate about and interested in physics practicum.

Finally, the lecturers and laboratory instructors suggested that VW CCCW could be used as a general tool in the hands-on physics practicum for documenting practicum data and, at the same time, as a space to assess the performance of practicum participants. Table 5 will provide an overview of some of the CCCW success feedback evaluated during the implementation of the project-based practicum from the participant.

Aspect	Descriptions
Educational Effectiveness	VW CCCW makes it easy to communicate and discuss significant matters quickly, as well as to attach different types of files
Ease of Use	Students ensure VW CCCW can be used easily with cloud data storage facilities and practical data collaboration work
	The practicum guide is easier to understand step by step because it is made interactive and dynamic
Engagement	Students think that they can do a quick review of the content of the short material and practicum guides in VW CCCW if they have problems
Environment	VW CCCW needs to be supported by a strong internet connection so that it is not constrained in data retrieval and implementation in general

Table 5: Participants' feedback on the VW CCCW project-based practicum, 2020

DISCUSSIONS

The Successful Use of VW CCCW Assistance in Practicum.

The successful use of VW CCCW in physics practicum must improve students' mastery of physics concepts. After VW CCCW was successfully integrated into practicum, Lecturers and Instructors of the Laboratory preferred using ICT in VW CCCW rather than doing traditional practicum because this method was better for improving student performance in practicum.

This finding follows the results of previous research (Darmaji et al. 2019) that ICT-assisted practicums in the form of mobile or web-based applications should be directed to foster better, interesting, meaningful, interactive cognitive experiences and foster social value. It shows that VW CCCW has a high value of effectiveness (Larsson et al. 2020) because students can access and study anytime and anywhere to achieve learning, not just replicating and extending practicum guides, student worksheets, animation, and video tutorial experiments (Mackay and Fisher, 2014). Students are more enthusiastic about carrying out practicum better to understand concepts (Koponen and Huttunen, 2013).

However, laboratory instructors have an essential role in the virtual team by positioning practicum participants into each group according to the results of the response before the practicum and facilitating and encouraging the team to produce productive results (Wang and Tahir, 2020). The practicum participants' performance can also be conveniently tracked and assessed by VW CCCW (Andamon and Tan, 2018) to significantly encourage laboratory instructors and lecturers of practicum courses for portfolio recording and practicum performance evaluation (Sarjono, Mardapi and Mundilarto, 2018).

Feedback from practicum participants from open questions and interviews has supported the application of VW CCCW in project-based practicum activities. Most of the practicum participants followed the project-based physics practicum with VW CCCW assistance. They expressed that they were challenged to think harder to make innovative, practical project products from the materials provided (Yusof, Awang Hashim and Kian, 2016). They also reflected that the animation and video on the practicum guide in VW CCCW could help them understand the physic concept in a contextual way to complete the practical product (Hung et al. 2020). Practicum participants from PU provided positive feedback on Educational Effectiveness and Ease of Use, namely the complete practical guide and stages in VW CCCW. Besides, they revealed that the practicum guide's text, images, and animated videos helped confirm the practicum process from anywhere, anytime, and time-efficient (Darmaji et al., 2019; Chiang, Yang and Hwang, 2014; Firmansyah et al., 2020). Feedback from SU practicum participants shows that CCCW is very helpful in communication and collaboration during practicum.

Participants in the practicum were satisfied that they could quickly revisit the quality of the short material and practical guide in VW CCCW after getting lost in the process (Cheung and Vogel, 2013). Other practicum participants will first communicate with their group members. If they cannot address the problem, they will finish the project according to the comprehensive practicum guide guidance (Mackay and Fisher, 2014). Practicum participants can communicate directly (discussion/chat), store data in the cloud, and work collaboratively on practicum observation data. Practicum participants can study the guidelines together before starting to complete the project as a practicum product. Several practicum participants mentioned that while working using VW CCCW, they could learn and complete assignments independently where previously they depended on the laboratory instructor's instructions (Pedaste and Sarapuu, 2014; Darmaji et al., 2019).

Practical Functions

All the features of the VW CCCW are believed to be suitable and successfully implemented to support the whole practicum stage. However, only three respondents, or 2.64% of the total respondents, considered that the archiving feature in the VW CCCW is not as necessary (neutral) due to the execution of actual practicum and project completion. At the same time, about 97.36% of students confirmed the success of using the archiving feature during real practicums. 12.5% of students answered that the collaboration feature in VW CCCW does not support practicum, while 87.5% percent said VW CCCW has succeeded in facilitating practicum to practice student collaboration skills (Basitere and Ivala, 2017).

Meanwhile, the monitoring feature also received a neutral response from students. At least 14 out of 104 students or

13.46% of respondents agreed that the monitoring feature was not crucial during the practicum. However, 86.54% of respondents positively confirmed the success of the monitoring feature in the practicum.

However, the VW CCCW feature was successfully used in project-based physics practicum. The evaluation results of the 4E model found that students considered the use of ICT in the form of CCCW virtual workspaces in project-based physics practicum positively (Kerr, Dale and Gyurko, 2019). Limited support for virtual Workspace CCCW during practicum (Voogt, 2009) indicates that VW CCCW can be recommended as a tool (assisted) in direct practice or project-based practicum to produce practical products (Zhai, Raver and Li-Grining, 2011).

CONCLUSIONS

Cloud Communication and Collaborative Work (CCCW) as a virtual workspace in a project-based physics practicum for prospective physics teachers have been successfully applied. The evaluation results show that the CCCW Virtual Workspace can be recommended as a practicum tool that is done directly (hands-on). Prospective physics teacher students expressed CCCW's effectiveness, ease of use, engagement, and environmental support, positively proving that project-based physics practicum successfully integrated ICT during its implementation. Functionally, the evaluation results of the features of the VW CCCW, namely communication, discussion, archiving, collaboration, monitoring, reviewing, and analysis, show positive results and are successfully used in guiding project-based physics practicum activities.

Implications

As an implication, the innovative application of VW CCCW in project-based physics practicum is a breakthrough as a tool for real practicum. ICT in physics practicum is not always well applied and too dominant, reducing process skills and not practising 4C skills. Therefore, as an implication in the 4.0 revolution era, workspaces can be a new way to work collaboratively with task management, creative action plans, communication and problem solving together, critical thinking and completing projects, and practicum performance evaluation and assessment.

As a new model practicum offer in the 4.0 industrial revolution era, VW CCCW can be used from the start before the practicum begins with an initial assessment (placement test). Practicum participants are placed in appropriate and proportional groups. In all stages of hands-on practicum, VW CCCW makes it easy to document data on the drive or cloud and collaborate and browse data from big data sources to solve problems and project tasks. In the post-practicum stage, students can prepare written and oral reports in the form of video reports to be sent to VW CCCW. Colleagues provide their comments and responses. Lab instructors or lecturers provide direction and improvement. Finally, the VW CCCW facilitates practicum performance assessment and records neatly in the analytical features. This new practicum model has a novelty both in ICT and the project-based practicum stage. The novelty of the model is the ease of communication and collaboration, which ultimately involves an authentic assessment process. The VW CCCW-assisted project-based practicum model can record student activities during practicum, meaning that student performance during the practicum process has measured by each performance and process skill trained.

As a further evaluation, the physics practicum has different topic characteristics. Therefore, the use of ICT cannot immediately replace a real practicum with a virtual practicum. VW CCCW is offered to answer the challenges of the 21st-century. VC CCCW can be used in virtual and real practicums; this depends on the characteristics of the physics topic.

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