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Development of Online Virtual Laboratory Platform for Supporting Real Laboratory Experiments in Multi Domains

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Abstract: The increasing use of online virtual laboratories (OVLs) in educational institutions as a recent educational technology application necessitates developing a new educational platform for assisting instructors in using such technology in the teaching process without web programming obstacles. The OVLs are online environments that provide students with several types of content such as simulations, videos, scientific images, and infographics related to real laboratory experiments. This article proposes a unified online virtual laboratory platform (OVLP) to support instructors who teach real laboratory experiments in multi-domains. To evaluate the proposed platform, five university instructors and five experts of ICT in education have participated in this study. The data were collected using online questionnaires for both specialists, respectively. Regarding the results, they confirm that the proposed platform is acceptable for teaching real laboratory experiments, especially in the tested domains.

Keywords: online virtual laboratories; specialized platform; distance education; supporting real laboratories

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1. Introduction

Recently, using learning technology applications has become a fundamental component in light of the digital transformation in the teaching and learning process. These applications would help instructors in presenting interactive learning content and achieving learning objectives effectively. Thus, several educational institutions are adopting varied applications such as distance learning systems, virtual learning systems, and mobile learning apps. The expansion of using distance and blended learning in schools and universities led to the emergence of many specialized learning platforms in several domains (such as [1–4]). The specialized learning platforms are web-based learning systems, including specialized functions, and content related to one domain or a group of similar domains. The specialized platforms consider a new trend in the educational technology field to support instructors in teaching students effectively. The main difference between specialized platforms and the existing LMSs is that the specialized platforms include functions related to learning in the target domains. Conversely, existing LMSs include general tools for learning content which make restrictions for instructors in teaching specialized learning content in some domains for students.

Nowadays, online virtual laboratories are considered a vital ICT tool for teaching practical skills related to real laboratory experiments. Recent studies confirmed that the many-sided positive impact of online virtual laboratories on the learning process [5–11]. The development of specialized online digital platforms would facilitate instructors' use and integrate modernistic ICT tools into the teaching process, especially in emergencies such as the COVID-19 pandemic.

One of the main challenges for instructors in schools and universities in the era of E-learning, who are responsible for integrating new effective technology such OVL into the future teaching process, is that they need to have a new specialized educational software to facilitate the use of such technology in teaching practical courses which have real laboratory experiments. Moreover, the most recent teaching methodology is depending on smart teaching. However, no unified platforms help the instructors create and manage the OVLs for real laboratory experiments without technical and programming obstacles in multi-domains such as science, economy, and histology.

This study proposes a new generic online virtual learning platform (OVLP) to help multi-domain instructors develop and combine interactive OVL in their teaching courses. To evaluate the proposed OVLP, we conducted usability evaluation throughout two qualitative experiments; one experiment focuses on instructor review to evaluate whether the proposed platform helped teach real laboratory experiments and met their teaching process expectations. Another experiment centered on expert review to evaluate the proposed platform's potentials to support real laboratory experience and instructors' usability about the main functions. Besides, we gathered suggestions and improvements for the current version of the OVLP. The results show that the instructors and ICT experts in education agreed that the platform could support instructors in schools and universities for established multi-domain OVLs in real laboratory experiments.

2. Platform Development

2.1. Platform Overview

In this section, we introduce the developed OVLP to support the learning of real laboratory experiments. The proposed platform is designed to cover a whole group of practical domains with real laboratory experiments like science, medicine, etc. The primary users of this platform are instructors and students in schools and universities. The OVLP consists of two modes, i.e., an instructor mode and a student mode. In the instructor mode, instructors can use 13 OVLP tools and have full authority to administer the tools, as shown in the following list and Figure 1.

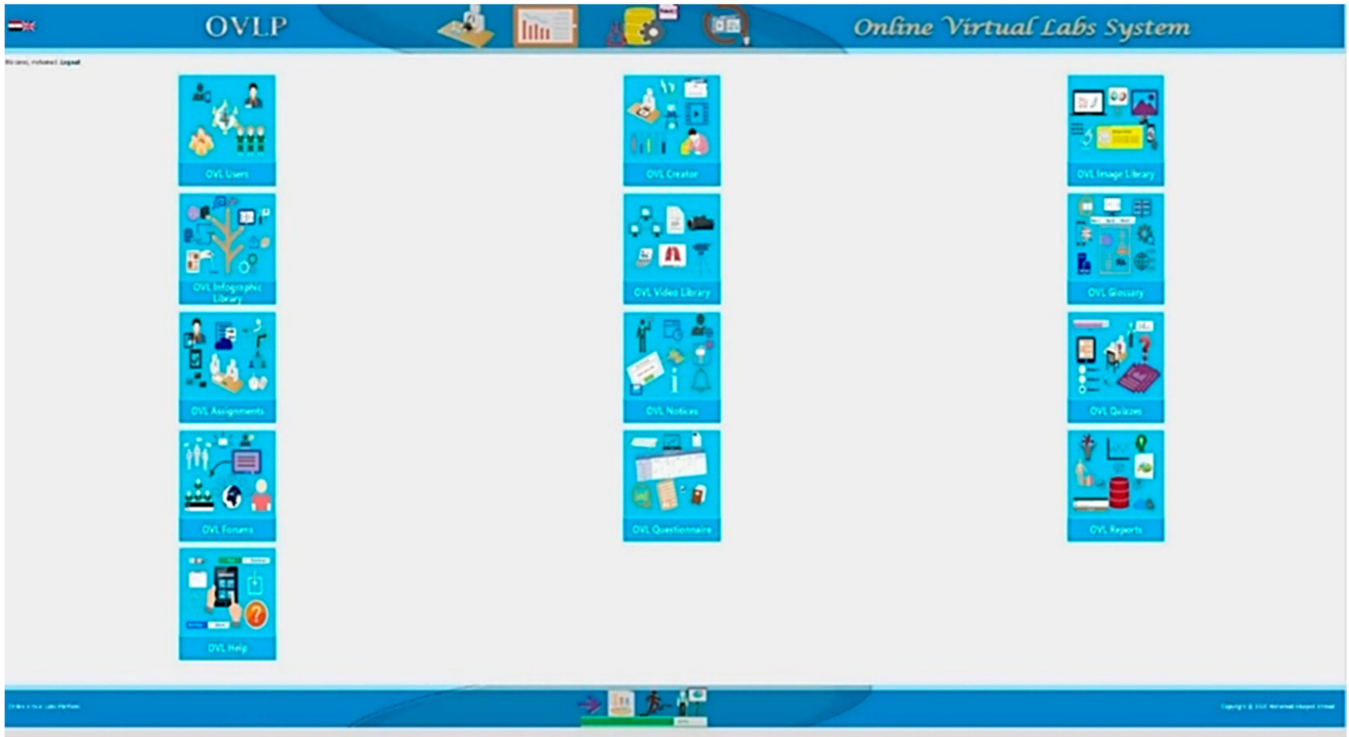

Figure 1. Instructor mode interface of the OVLP.

1. OVL Users provides a login system for the OVLP to both instructors and students, including user account management.
2. OVL Creator constructs and publishes the OVL framework contents, virtual experiments for various educational domains, quizzes, and forums.
3. OVL Image Library manages a scientific image library regarding the OVL domain.
4. OVL Infographic Library handles an educational infographic related to OVL and virtual experiments contents.
5. OVL Video Library deals with an educational video library for students related to the OVL domain.
6. OVL Glossary provides an online glossary of terms with multimedia for OVL content.
7. OVL Assignment supports an online assignment for students and receives answer files for OVL content.
8. OVL Notices shows notices for students of the OVL.
9. OVL Quizzes constructs OVL quizzes with multimedia questions for students and receives their answers.
10. OVL Forums provides discussion forums regarding the OVL contents.
11. OVL Questionnaire constructs a questionnaire related to OVL.
12. OVL Reports generates reports for students' quiz scores, questionnaire responses, and log activities.
13. OVL Help creates an online help with multimedia for OVL students.

The student mode provides the students with 12 tools and interactive content of OVLs. Figure 2 shows the main learning activities in the OVLP. The key technologies for the OVLP are UML, CakePHP framework, HTML, CSS, and MySQL database, in addition to Adobe Photoshop and Edraw max. We have already tested all the tools practically to ensure the target operation of the OVLP without technical problems. A ready-made template function for OVL image library tool is shown in Figure 3. The OVLP can run on the IIS server as a web application for operational use.

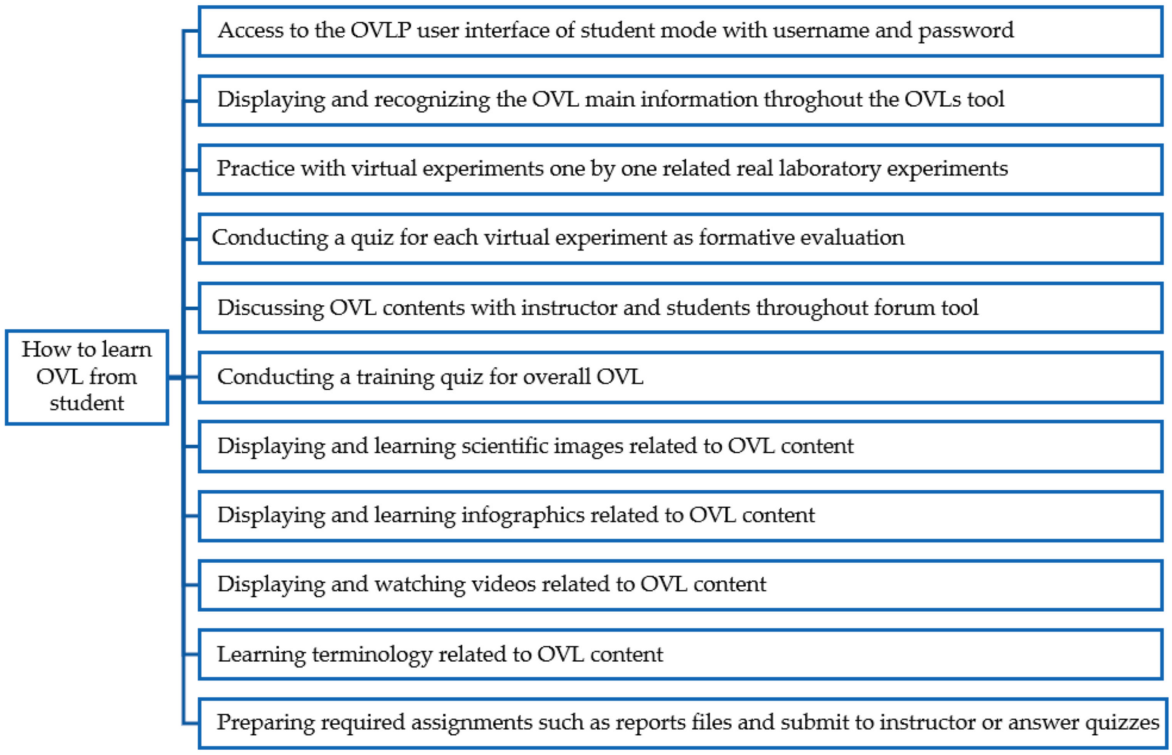

Figure 2. Main learning activities of OVL from student in the OVLP.

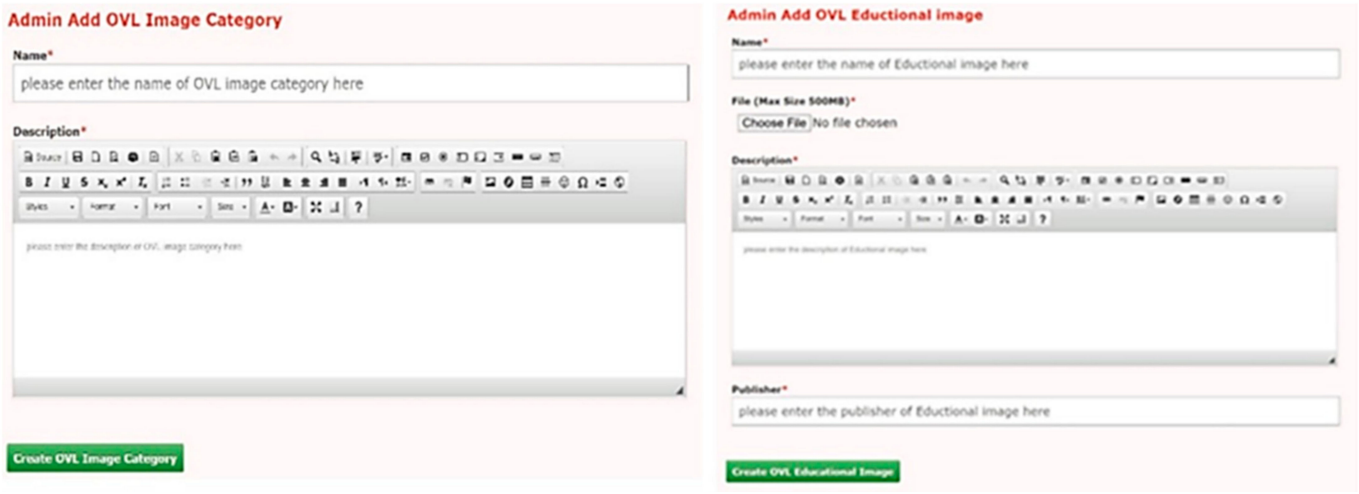

Figure 3. Ready-made templates for creating OVL image library.

Our previous work [12] focused on testing the effects of a virtual learning platform on improving students' skills in designing and producing OVL. In the developed OVLP, we enhance several functions to enable instructors to establish OVLs in multi-domain quickly. New tools are added to the main functionality enhancements such as the OVL infographic library tool, and OVL video library tool for OVL contents also added an OVLs tool to display the created OVLs to students. The OVL creator also updates the proposed platform with a ready-made template for creating virtual experiments, including new features such as video for real laboratory experiments and references, the OVL image library with publishing features, the OVL forums tool with comments feature.

2.2. Advantages of the Proposed OVLP

The design philosophy of the current version of the OVLP was summarized as expected advantages as follows:

1. Unified platform for multi-domains: It includes a fixed creation way for OVLs suitable for various domains.
2. Effective learning materials: It presents varied OVL content learning material for students like laboratory video, simulation, scientific image, and educational infographics.
3. Searchable content: It saves time for instructors and students by a search function for OVL content.
4. Informative terminology glossary: It supplies students with a term list for OVL content, including image/graphics/video besides text definition.
5. Multimedia quizzes: It includes ready-made templates to ask questions for scientific images, video, and audio.
6. Interactive supports: It provides interactive discussion forums for students related to OVL contents.
7. Online formative evaluation: It assists students to detect their learning progress for knowledge and skills of experiments during the learning process through formative quizzes.
8. Student performance report: It provides instructors with reports for student activities such as grades and log activities.
9. Flexible online learning tool: It provides instructors with several integrating styles in the learning process like OVLP pre-real laboratory, OVLP during real Laboratory, OVLP after real laboratory, OVLP Pre and after real laboratory, and OVLP Pre, after, during the real laboratory.

2.3. Content Development by Instructor with the OVLP

The OVLP features are support instructors in schools with ready-made templates for creating learning content of OVLs without programming obstacles. Instructors can input the learning content of OVL directly inside the proposed platform. Regarding upload files of learning materials in the creation processes such as simulation, video, educational images, and infographics, they can upload existing files or developed new materials related to OVL educational objectives. The development of the OVLP learning content required the significant participation of real laboratory instructors. Figure 4 shows a creation process for OVL contents by instructors with the proposed OVLP. The following is an example of the creation steps of OVL contents for a science course real lab.

1. Create the OVL framework of real science lab including:
    - Create OVL of science contains main information (name, target students, domain, General Objectives, main Topics)
    - Add virtual experiments to OVL of science includes (experiment title, educational objectives, theoretical explanation, Instructions/Procedures, experiment simulation file, experiment video file, activity, summary, references), besides adding quiz for the virtual experiment.
    - Add a discussion forum to the lab
    - Add training quiz to the lab
2. Create an image library for the OVL of science including:
    - Create images categories related to the OVL of science contents
    - Add OVL educational images inside each category.
3. Create an infographic library for the OVL of science including:
    - Create infographics categories related to the OVL of science contents
    - Add OVL educational infographics inside each category.
4. Create a video library for the OVL of science including:
    - Create videos categories related to lab contents
    - Add OVL educational video inside each category.
5. Create a glossary for the OVL of science including:
    - Create glossary table information (name, description)
    - Add OVL educational terms inside each glossary.
6. Create Assignments for students including:
    - Create new assignment (title, description, deadline, attachment file)
    - Receive assignment files from students.
7. Create a general forum for the OVL of science contents
    - Create a new forum (name, forum instruction)
    - Add Topics to Forum.
    - Add Posts to Topic.
    - Add Comments to Post.
8. Create a summative quiz for the OVL of science contents
    - Create a new Quiz (title, instruction, score, time)
    - Add Questions to the Quiz.

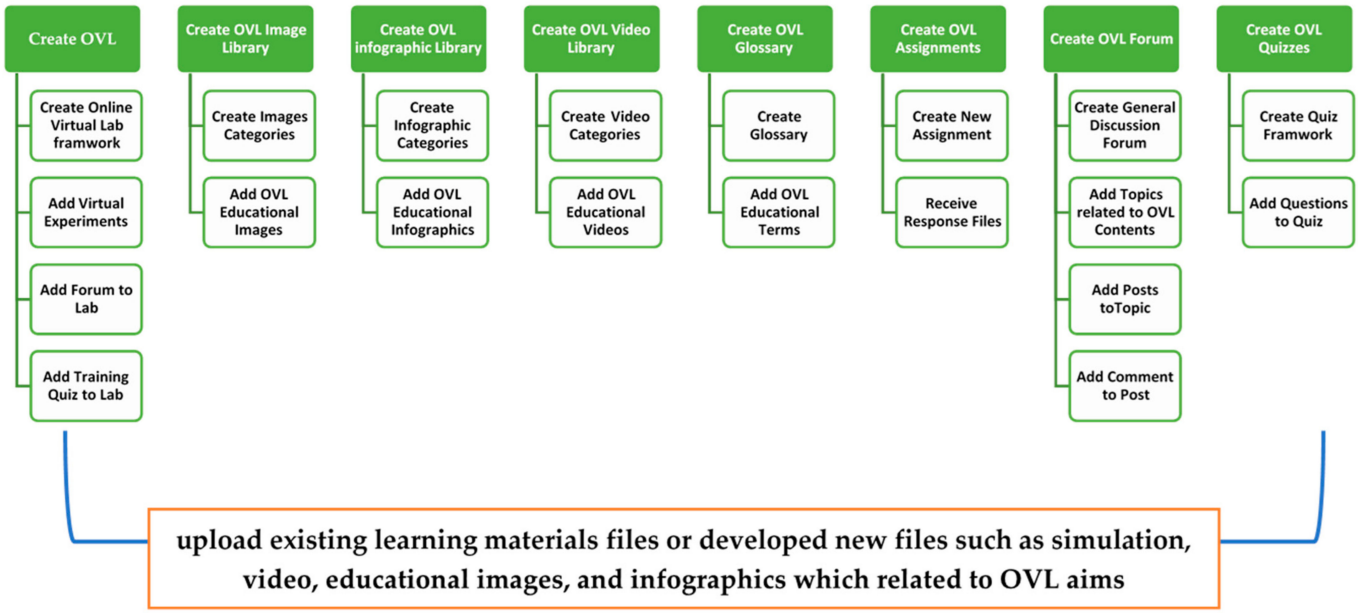

Figure 4. Main steps for Instructor creation of OVL contents.

2.4. Student Benefits from the Proposed Platform

Based on the inference of the current usability evaluation process of the proposed platform and the characteristics of the function tools, the proposed OVLP have provided several benefits for final user students in learning multi branches domains of science, medicine . . . etc. as follows:

1. Students can learn real laboratory experiments with various learning materials such as interactive simulation, video, scientific images, and infographics and display hidden phenomena in a real laboratory.
2. It helps students acquire practical skills elaborately by repeating virtual experiments several times.
3. It provides flexible learning at any time and place for students.
4. It provides lifelong learning for practical experiments out of schools and universities via the internet.
5. Students can learn terminology related to OVL contents illustrated with images, graphics, and videos or sounds.
6. During learning with proposed OVLP, students can conduct self-evaluation regarding OVL content through various quizzes and receive direct feedback.

3. Platform Evaluation

The OVLP usability evaluation was implemented to gather ICT experts in education and instructors' opinions toward the proposed OVLP and identify the availability and usability problems of the developed platform from the perspectives of instructors of different subjects and ICT experts in education throughout two experiments: one experiment concerning instructor review, and another experiment focused on expert review. We used the same version of the proposed platform in the two experiments. We designed two online questionnaires: one for instructor review and another for expert review. We collected and analysed experts' and instructors' opinions and comments toward the platform. These usability evaluations took into account ethical considerations. The formal consent was obtained from the ICT experts in education and university instructors. The limited number of participants is because the research experiment was conducted face to face, and we have been affected by the COVID-19 pandemic in gathering some more participants. There is no student voice in the study because we are limited to evaluating the proposed platform by instructors and experts, and the current version does not include OVLs learning content

for students in this research stage. The usability evaluations did not have any harmful effects mentally and physically. The following are details about the instructor review and expert review.

3.1. Instructor Review

3.1.1. Participants

The testing participants were five university instructors from Egypt between 32 and 39 years of age (Mean = 36.2, SD = 2.59). They had teaching experience from 11 to 17 years (Mean = 14.4, SD = 2.19). All of them were assistant professors (lecturers) from colleges of science (3) and veterinary medicine (2) at the same university. The teaching domains were Phycology, Plant Systematics, Geology, Health, and Histology, respectively. They were assigned to one training session with the proposed OVLP on 22 July 2020.

3.1.2. Procedure

To conduct the experiment training with the English version of the proposed platform, they used a computer lab at the university to which they belonged. We provided the electronic guide of the OVLP, and the user accounts for the instructor and student modes before the training. They first accessed the platform from the web browser and then trained to use the developed tools together with the one researcher. After finishing their training session, they responded to an online questionnaire for instructors. The usability evaluation took around 100 min.

3.1.3. Instrument

The questionnaire for instructors was designed by recent studies about online virtual laboratories, ICT for instructors, and system development [13–18]. This questionnaire aimed to evaluate the usability evaluation of the proposed OVLP in terms of usefulness for teaching real laboratory experiments, interest to use, the timing of use, and platform design. It contained six sections, including closed questions formulated in positive design with a five-point Likert scale (5: Strongly Agree, 4: Agree, 3: Neutral, 2: Disagree, 1: Strongly Disagree) and an open question with the following sections.

Section 1: Demographic information for instructors.
Section 2: Seven closed questions to assess whether the proposed platform would help instructors teach real laboratory experiments.
Section 3: Three closed questions to confirm whether the proposed platform would be an exciting teaching tool for instructors in schools and universities.
Section 4: Three closed questions to gather preferences of teaching time to use the platform.
Section 5: Four closed questions to detect the quality of the platform design.
Section 6: One open question related to instructors' comments for the proposed platform.

3.1.4. Results and Discussion

Table 1 presents the instructors' perceptions regarding the proposed OVLP as follows: In Section 2 most instructors confirmed that the proposed OVLP was supporting real laboratory experiments, and then in Section 3 most of them confirmed that the proposed OVLP was interested in using their teaching process. The majority of the instructors confirmed that the proposed OVLP was suitable for teaching real experiments, whatever was used before, during, and after real laboratory in Section 4, and they basically agreed that the OVLP had a good design in Section 5.

Table 1. Instructors' Perceptions Regarding the proposed OVLP.

Evaluation Items	SA	A	N	D	SD	Median
Section 2: Helpful for teaching real laboratory experiments						
1. Using the OVLP is suitable for teaching the practical side of the courses in general.	3	2	0	0	0	5
2. The OVLP would help create the OVL for the real laboratory experiments of the target course.	3	2	0	0	0	5
3. Using such a platform would help support the achievement of the educational objectives of a real laboratory.	1	4	0	0	0	4
4. Using such a platform would help in teaching real laboratory experiments more effectively.	1	4	0	0	0	4
5. The OVLP can be used as a smart teaching tool.	3	1	1	0	0	5
6. The OVLP would provide a diversity of OVLs contents.	3	1	1	0	0	5
7. The OVLP would be useful for OVLs management.	3	2	0	0	0	5
Section 3: Interest to use the OVLP						
8. I would like to teach with the OVLP in the coming practical course for real laboratory experiments.	1	4	0	0	0	4
9. I expect that teaching real laboratory experiments with the help of the OVLP would improve learning outcomes.	3	2	0	0	0	5
10. I would recommend using such a platform to other instructors.	5	0	0	0	0	5
Section 4: The timing of using the OVLP in the teaching process						
11. Using such a platform would benefit students before conducting a real laboratory experiment.	3	1	1	0	0	5
12. Using such a platform would benefit students during conducting a real laboratory experiment.	2	2	1	0	0	4
13. Using such a platform would benefit students after conducting a real laboratory experiment.	2	3	0	0	0	4
Section 5: Platform design						
14. It is easy to use such a platform.	5	0	0	0	0	5
15. The OVLP user interface is appealing.	3	2	0	0	0	5
16. The OVLP functions work very well.	4	1	0	0	0	5
17. The OVLP functions come with a guide with hints/messages for users.	4	1	0	0	0	5

Section 6: Four instructors shared their overall recommendations and suggestions for the proposed OVLP. Their comments were concluded as follows:

- "Increase the size of the pictures to more than 500 MB."
- "I recommend putting examples of previous virtual labs."
- "I recommend expanding the input tools to facilitate the various disciplinary science to achieve the targets."
- "I would like to apply this platform to my students as soon as possible."

The tested domains were related to instructors' teaching domains. The tested domains included Phycology, Plant Systematics, Geology, Health, and Histology. The instructors confirmed that the proposed tool is suitable for their domains. The proposed platform design was generic, so the development of the tool was focused on covering all domains of science, medicine ... etc. The virtual experiment ready-made template on the platform was included (experiment title, educational objectives, theoretical explanation, instructions/procedures, experiment simulation file, experiment video file, activity, summary, references) and it was taken into account that the learning content of the virtual experiment is varied according to the type of real laboratory experiment. Thus, the main uploaded files of the virtual experiment template such as the simulation file and experiment video file of

each experiment are changeable according to the real laboratory experiment type. Based on the successfully tested domains, it can be claimed that at least the functions required in these domains were confirmed to be covered.

3.2. Expert Review

3.2.1. Participants

The participants of this experiment were five experts in Japan between 29 and 37 years of age (Mean = 34.2, SD = 3.56). They had experience related to ICT in education ranging from 2 to 10 years (Mean = 6.6, SD = 2.97). Four of them were Ph.D. students in research labs interested in education/learning informatics, and the remaining was an assistant professor in the same university. All of them were assigned to one training session with the proposed OVLP on 14 April 2020.

3.2.2. Procedure

The procedure was almost the same as the instructors' evaluation. Furthermore, they responded to an online questionnaire for experts of ICT in education. It took around 140 min.

3.2.3. Instrument

For this experiment, the online questionnaire for experts of ICT in education was designed to achieve expert review. The questionnaire was prepared specially for this study and was guided by recent studies about online virtual laboratories, ICT for instructors, system development, and sustainable development goals [13–19]. This questionnaire aimed to evaluate the usability evaluation of the proposed OVLP in terms of the importance of the OVLP to real laboratories, usefulness to instructors, main features of the platform functions, support sustainable development goals, and platform design. It contained seven sections, including closed questions formulated in positive design with a five-point Likert scale the same as the instructors' one and some open questions at the end of each section related to the reasons for selecting their responses, mostly strongly agree and strongly disagree. The following is the detail of each section.

Section 1: Demographic information for experts.
Section 2: Four closed questions to assess whether the proposed platform was essential to support real laboratories' learning process.
Section 3: Four closed questions to confirm whether the proposed platform was useful for instructors in schools and universities.
Section 4: Twelve closed questions to evaluate whether each proposed function was useful for OVLs.
Section 5: Three closed questions to gather whether the proposed platform contributed to support sustainable development goals.
Section 6: Four closed questions to detect the quality of the platform design.
Section 7: One open question related to experts' comments for the proposed platform.

3.2.4. Results and Discussion

Section 2: Table 2 indicates that most experts agreed on the importance of the proposed OVLP to real laboratory experiments.

Table 2. Experts' perceptions of the importance of the OVLP to real laboratories (n = 5).

Evaluation Items	SA	A	N	D	SD	Median
1. The OVLP is considered a new virtual learning solution for enhancing the learning of real laboratory experiments.	0	3	2	0	0	4

Table 2. *Cont.*

Evaluation Items		SA	A	N	D	SD	Median
2.	The OVLP is considered a unified platform suitable for creating online virtual laboratories (OVLs) in multi educational domains.	0	4	1	0	0	4
3.	Using such a platform would contribute to overcoming real laboratory obstacles (like high costs, invisible phenomena, maintenance, etc.).	1	2	2	0	0	4
4.	Using such a platform would support lifelong learning for real laboratory experiments.	2	2	1	0	0	4

The reasons for their responses for this section of "strongly agree" were also collected. One of the experts said that "The system is capable of handling multiple domains. I think it is very useful for lifelong learning that anyone, anywhere, can study a domain that interests them." In addition, another expert stated that "This type of virtual lab can remove the distance and save time for the educators and learners and also cost-effective."

In addition, some of the experts made comments for improving the current version of the platform. One of them described that "It is quite complex that requires time to understand how to use. But the system is complete." Another expert pointed out that "For all items (1–4), the proposed system's objective is important in education. However, the implementation has to be well designed before building the system. The current system still needs more technical improvement and to be more organized." The other expert claimed that "different academic domains have specific requirements for conducting experiments. Hence, I am not sure whether the platform has the required flexibility and scalability to meet the differences." In conclusion, most of their opinions and feedbacks related to the platform were important for real laboratory education.

Section 3: Table 3 showed that the experts confirmed that the proposed platform was useful and helpful for instructors in teaching real laboratory experiments to create and publish the OVLs without web programming difficulties, enabling them to provide students with OVL multi learning styles with pre-set OVL contents.

Table 3. Experts' perceptions of the OVLP usefulness to instructors (n = 5).

Evaluation Items		SA	A	N	D	SD	Median
1.	The OVLP would help the instructors in teaching real laboratory experiments more efficiently.	1	3	1	0	0	4
2.	Using such a platform would assist instructors in creating and publish the OVLs without web programming difficulties.	1	3	1	0	0	4
3.	Using such a platform would enable instructors to provide students with OVL multi learning styles.	1	3	1	0	0	4
4.	Using such a platform would assist instructors in teaching efficiency with pre-set OVL contents.	0	4	1	0	0	4

Some of the experts shared their opinions for this section. One of them said that "An instructor can use different multimedia contents on the same topic, the flexibility of using diverse content can make the teaching more efficient, understandable to the learners and provide motivation and multi-learning to them. Using this type of easy instructional guide, any instructor can develop and deliver content without enough programming knowledge." Another one stated that "The proposed system is useful for teachers, especially in preparing the student. However, the current system, especially the interface, is still not user friendly, not really well organized (e.g., no Navigation pane and sitemap that would make users easy to track where they are in the website)." On the other hand, one of the experts mentioned that "This system is multi-functional. However, I think it is difficult for a teacher who uses it for the first time to master it fully. Until you get used to it, you may need some support, such as making it simple to use." Besides, one of the experts claimed that "To support different learning styles, instructors might need to create different

teaching modes for the same contents. Having to do so might refrain the instructors from using the system because of time-consuming." In summary, most of the experts' feedback reported that the platform was beneficial for instructors in schools and universities to teach real laboratory experiments.

Section 4: As shown in Table 4, most experts assured that all the proposed functions of the OVLP were useful for OVL.

Table 4. Experts' Perceptions Regarding the Main Feature of Platform Functions (n = 5).

Evaluation Items		SA	A	N	D	SD	Median
1.	Constructing and publishing the OVL framework contents and virtual experiments for various educational domains are useful.	1	4	0	0	0	4
2.	Constructing a scientific image library regarding the OVL domain is useful.	1	3	0	0	1	4
3.	Constructing an educational infographic library related to OVL and virtual experiments contents is useful.	1	3	0	0	1	4
4.	Constructing an educational video library for students related to OVL domain is useful.	2	2	0	0	1	4
5.	Constructing an online glossary of terms with multimedia for OVL content is useful.	2	2	0	0	1	4
6.	Constructing an online assignment for students and receive answers files for OVL content is useful.	3	2	0	0	0	5
7.	Constructing notices for OVL students is useful.	2	2	1	0	0	4
8.	Constructing an OVL quiz with questions that contain multimedia for students and receive their answers is useful.	3	1	0	0	1	5
9.	Constructing a questionnaire related to OVL is useful.	2	1	1	0	1	4
10.	Constructing discussion forums regarding the OVL contents is useful.	2	1	2	0	0	4
11.	Generating reports for students' quiz scores and log activities are useful.	2	2	1	0	0	4
12.	Creating an online help case with multimedia for OVL students is useful.	1	1	2	1	0	3

Most of the experts gave feedbacks that the platform function tools were useful for OVL. For example, one of them said that "Image, video, simulations, infographics, and other diverse contents provide the opportunities for multi-dimensional learning styles, especially, images, videos, and simulations are powerful contents to create an immersive learning environment for the learners. Learners will not feel boring. Submitting assignments and reports, receiving necessary notices, instruction, discussion with peers and instructors makes the teaching and learning more flexible and acceptable." Another one stated that "I think the functionality of this system is useful. However, as I wrote before, I think it is important that teachers can use these functions and really create a useful library when they use them in actual educational settings." On the other hand, in short, one of them mentioned that providing various education domains in one platform was useful, and all functions were also essential. He also presented suggestions for improving some tools like user interface and merging some functions in one. Besides, another expert claimed that the "online help case is sort of similar to the forum. YouTube is a good source of videos for learning purposes. What is the advantage of video on OVL over YouTube videos? How about using YouTube as a video database and the OVL for organizing the video by categories?" Another expert mentioned that "In glossary is ok but consider using Ontology style where there are relationships and multilevel concepts. For image/infographic/video-instead of putting into a category only you may try to add a tag such as I may have about #java #video #string and array and the user can search by tag. The category may have the hierarchy (Ontology)." In summary, most of the experts' opinions related to the proposed function tools were important for OVLs.

Section 5: Table 5 indicates a more reasonable relationship between the proposed platform and some sustainable development goals related to education, health, and the

environment. The experts confirmed that the OVLP was supportive of such sustainable development aspects.

Table 5. Experts' perceptions regarding support some sustainable development goals (n = 5).

Evaluation Items		SA	A	N	D	SD	Median
1.	The proposed OVLP would help achieve quality education as a sustainable development requirement in schools and universities.	0	3	2	0	0	4
2.	The proposed OVLP would help ensure students' safety by reducing harmful or dangerous experiments in schools and universities.	2	2	1	0	0	4
3.	The proposed OVLP would help preserve the environment in schools and universities.	1	1	1	2	0	3

Experts' reasons for their responses for this section related to "strongly agree" were also collected. One of them said, "Of course, virtual experiments can save pupils and instructors from the harmful chemicals and other harmful emissions. It can be eco-savvy and environmental friendly. Many topics could be taught fully through virtual labs. But there are also many experiments which are needed to be tested and done in a real lab environment. In this case, virtual lab contents can provide some ideas to do the action in the practical experiment." Another one pointed out that "OVLP might encourage students to maintain their interest in lifelong learning." Additionally, the other said that "As for sustainability, I think it depends on how well we can build environment (library and quiz and...etc.) that can be used properly." On the other hand, one of them described that "I do not really understand the correlation between the system and the sustainable development requirement." In conclusion, most of the experts' feedback confirmed that the platform was considered a supportive system for sustainable development goals.

Section 6: As illustrated in Table 6, most experts approved the proposed platform's current version design to be acceptable.

Table 6. Experts' perceptions regarding platform design (n = 5).

Evaluation Items		SA	A	N	D	SD	Median
1.	The OVLP user interface is appealing.	1	1	1	1	1	3
2.	The OVLP functions are worked very well.	2	1	2	0	0	4
3.	The OVLP is easy to use.	1	0	2	2	0	3
4.	The OVLP functions are provided a guide hints/messages for users.	2	1	0	2	0	4

The experts reported the following comments:

- "The OVLP is easy to use for teachers-for the first time, it is difficult to use; for example, creating a quiz and choices are difficult. For example, 20 questions with 4 choices would require 80 actions; to complete creation."
- "Creation procedure takes several steps which are currently separated. I think they could be group into one screen to help the composer create content with ease and in a complete manner."
- "I'm curious about the details—for example, the position of a button (ex. The Admin dashboard) maybe second from the top on some screens, and a button's position may be at the bottom of others. If it is a frequently used button, I think it would be good to display it at the top of all buttons. It would be better if I could fix some of the details."
- "Item 1. It's colorful and unique, item 2. Some functions do not work, item 3. It's easy but less organized, therefore not really user-friendly. The navigation pane and sitemap would be very helpful, and item 4. The action buttons placed on two sides of the page and the guide need to be more eye catchy."

- "Yes, it is simple, sequential, and easy to follow the instructions and could be operated without much hassle."

Section 7: Four experts shared their suggestions for improving the overall platform as follows:

- "It is a good system and will be greater if designed with a more user-friendly interface."
- "You may add the idea of both asynchronous and synchronous distance teaching and learning concept. I think this platform represents both aspects."
- "Workflow mechanism might improve the User Experience for the platform."
- "Have you considered mobile phone users? The recent day, many students use a mobile phone, so please design for mobile phone user friendly. All the functions are useful, only a few comments like "topic/post/comment" please use something like tree view for make it easier to understand the hierarchy, If the contents like photos, infographics can be share when creating the lab so the user no need to re-upload again, the virtual lab file using .swf? I think this is quite outdated now as many browsers do not support it anymore and we can show the link of YouTube video instead of upload the video will save you much space required."

In summary, the usability evaluation results showed that the majority of ICT experts in education and university instructors have the same perspective that the current version of the OVLP can be used to support learning of real laboratory experiments, of which at least the developed functions were suitable for these domains. Some participants gave improvements related to aspects of the user interface and platform functions. However, the current usability evaluation detected some practical issues related to the proposed platform such as the design of the user interface, simplicity to use, less organization, and some technical points for some functions.

While many academic online laboratory platforms exist related to the proposed platform, some of the literature focused on developed platforms for one domain, such as [20], proposed a virtual experimental platform for chemistry laboratory experiments, and [21] suggests a virtual laboratory platform innovate engineering education. Moreover, [22] presented a virtual experiment platform for students in the civil engineering specialty. Additionally, [23] presented a digital circuit virtual laboratory. Compared with this literature, our developed platform is a generic online virtual laboratory platform suitable for multi-domains to help instructors in schools and universities create and teach OVLs of real laboratory experiments. On the other hand, this literature focused on student learning aspects and did not focus on developing a generic framework that assists instructors in creating, integrating, and using OVL for real laboratories experiments. The need for technical expertise in order to create and develop OVL experiments is found challenging by instructors from non-technical domains. The generic platform for helping such instructors carry out laboratory experiments will definitely support the use of the OVL in schools and universities. Additionally, the proposed OVLP is a specialized platform that includes more features related to learning real lab experiments from a pedagogy perspective. This feature includes increased visual learning for OVL content, such as scientific image library, infographics library, video library, glossary with multimedia. Additionally, there are other pedagogy aspects, for example, the OVL general objectives, educational aims for each virtual experiment, E-activities, self-assessment, and a summary of each experiment.

The current study was conducted with a small sample size of 10 participants (university instructor = 5 and ICT experts in education = 5) but it is still acceptable for usability evaluation. However, implementing this study with a larger sample size will maybe generate more precise results.

4. Conclusions

In this study, we developed a new generic platform for enabling instructors to create OVLs in multi-domains. This developed platform helps instructors in schools and universities in the teaching of real laboratory experiments. The OVLP was evaluated throughout usability evaluation in two experiments: the instructor review and expert review. The

participants in the study were five university instructors and five experts of ICT in education. The participants were trained with the English version of the proposed platform that we developed. The study collected data using two online questionnaires for instructor review and expert review. The findings showed that the instructors had a positive attitude towards the platform as an ICT solution for teaching real laboratory experiments, especially in the tested domains. Additionally, we confirmed that the experts in ICT in education agree to the OVLP created. The usability evaluation results of the OVLP confirm that the OVLP established is suitable to apply in the teaching process of real laboratory experiments. However, the ICT experts in education suggested some concerns for the current version related to the difficulty of use for the first time for instructors, technical issues, and flexibility and scalability to meet the differences of multi-academic domains. The proposed platform will be updated based on the usability evaluation results. The student evaluation is also the next stage of this research, which will test the impact of the proposed platform in enhancing student learning in multi-domains of real laboratory experiments.

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