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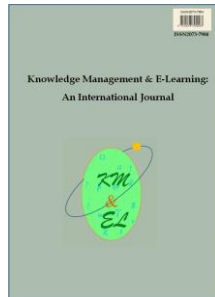
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## **The effects of a new virtual learning platform on improving student skills in designing and producing online virtual laboratories**

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**Abstract:** The expanding use of virtual learning applications in educational institutions requires educators to enhance their skills in the design and production of these applications. A novel VLP was proposed in this study to cultivate students' skills in designing and producing online virtual laboratories (OVLs). To examine the effects of the VLP, thirty Year-4 undergraduate students majoring in educational technology participated in this study using a pre- and post-test design. The data were collected using online instruments; an achievement test, a performance observation card, a product evaluation card, and a usability questionnaire. The results showed that the proposed VLP was effective in increasing student knowledge and practical skills required to design and produce an OVL. Students found the VLP to be a comfortable way for learning relevant knowledge and skills.

**Keywords:** Virtual learning platform; Online virtual laboratories; Educational technology; Design skills

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## **1. Introduction**

Information and communication technology (ICT) have become an essential component of advanced educational systems. These educational systems are expanding the integration of virtual learning applications such as virtual learning systems, virtual classrooms, and virtual laboratories in the educational process.

A virtual learning platform (VLP) is a web-based system, which contains educational tools and interactive contents. The systems enable instructors to create, manage and deliver online learning courses, activities, and formative and summative evaluations through synchronized and asynchronized communication, anytime, anywhere. The VLP is considered to be one of the modern applications of technology in renovating education because it works to increase students' interactivity and technological competencies with learning process management and performance monitoring. Thus, the VLP can be integrated into traditional educational technologies as a blended learning method and for distance learning. In addition, it could raise the students' levels of understanding learning contents through the availability of sufficient and repeatable training. Also, it could promote students' motivation (Chiu & Li, 2015).

The virtual laboratory is considered as a new ICT application for improving education. This application has many advantages regarding aspects of economy, richness, safety, sufficiency, supportive real labs, motivation, understanding, interactivity, accessibility, creation, integration with online courses (Ahmed & Hasegawa, 2014). Recent empirical studies that addressed virtual laboratories have confirmed a significant impact in enhancing the practical skills and achievement of knowledge for target learners in various fields of science across educational stages. Examples include the physics-related academic achievements and process skills of tenth graders (Yang & Heh, 2007), undergraduate students' conceptual understanding of electric circuits (Zacharia, 2007), conceptual knowledge regarding electric circuits and procedural skills of secondary vocational engineering education (Kollöffel & de Jong, 2013), undergraduate students' photoelectric concepts (Bajpai, 2013), elementary school students' science learning (Sun, Lin, & Yu, 2008), conceptual understanding and science process skills of fourth grade primary school students (El-Sabagh, 2011), high school students' achievement levels and attitudes towards chemistry (Tüysüz, 2010), seventh grade elementary pupils' knowledge regarding chemical topics (Herga & Dinevski, 2012), scientific process skills related to chemistry for first grade pre-service science teachers (Mutlu & Şeşen, 2016).

Outside of the science fields, there are several studies such as computer networking skills (Lampi, 2013), and pharmacology education showing students' confidence and skills in the real laboratory in addition to decreasing experimental accomplishment times (Cheesman et al., 2014). Based on analysis of these previous studies, the virtual laboratories have demonstrated a valuable impact on the learning process.

However, educational technology students often do not have the necessary skills to design and produce OVLs to use as a new technology tool in education because the previous research focused on the impact of virtual laboratory technology in a specific domain. To the best of our knowledge, besides, there is no systematic method or curriculum, and no class offered which teaches students how to design and produce OVLs in the current academic programs of most of the educational technology departments in Egyptian universities including our university. Therefore, it is necessary for specialists in education, especially those students majoring educational technology, to develop the skills of designing and producing OVLs as part of the core curriculum. These

students will require the ability to implement such technology in future schools and universities. Academic programs in universities should also include education on how to design, develop, utilize, combine, and evaluate modern ICT applications in order to improve the quality of education as a whole. Students specializing in educational technology need to expand their skills for the era of e-learning and virtual learning, especially in the design and production of OVLs. In this context, an OVL is defined as a web-based environment which includes virtual experiments, discussion forums, quizzes for real laboratory experiments, invisible phenomenon, skills, theories, and concepts related to the specific educational course.

In this study, we propose a new VLP for developing the general skills of designing and producing an OVL for educational technology students. The main feature of the VLP is to give the target students specialized tools in the practice of design, production, and distribution of OVLs in a consistent way. It also provides an online course focused on providing the knowledge and skills needed for designing and producing OVLs. To investigate the effectiveness and usability of the proposed VLP, we performed an empirical experiment with undergraduate students majoring in educational technology. Specific instruments were used to evaluate learning outcomes and usability. At the end of this study, the educational technology students designed and produced their own OVLs. The results show that this VLP significantly improves student achievement and skills in designing and producing OVLs.

In order to realize a systematic education for OVLs, this study focused on two research questions. RQ1: What is the effectiveness of the proposed VLP in developing skills of designing and producing OVLs of educational technology students? RQ2: What is the usability of the proposed VLP from the perspective of the educational technology students?



Fig. 1. Dashboard for instructor on the VLP

## 2. Development of the VLP

The VLP we developed consists of two modes an instructor mode and a student mode. In the instructor mode, the instructor has full authority for administration of the VLP tools as shown in Fig. 1. The student mode provides the students with interactive contents and specialized tools to design and produce their own OVLs. The VLP was developed using

UML, CakePHP framework, PHP, CSS, JavaScript, and MySQL database applications. In addition, the VLP educational contents were developed by the VLP course tool and screen recording program. The current version of the VLP supports two languages - English and Arabic. The VLP was installed on a LAMP (Linux-Apache-MySQL-PHP) server and was tested in the real environment. After debugging, the VLP was ready for field use.

### 2.1. Innovative tools for designing and producing OVLs

The developed VLP contains several distinctive functions including innovative tools for designing and producing OVLs easily and without specialized technical knowledge. These tools are described in Table 1.

**Table 1**

The main VLP tools for designing and producing OVLs

<b>Tool description</b>	
OVL designer tool	This tool enables students to design the OVL by providing a group of ready-made templates. These templates allow students to design an OVL framework, OVL platform, virtual experiment, and overall evaluation.
OVL creator tool	This tool provides students with a template-based production function for the OVL without any code programming. This tool enables students to create the OVL framework automatically after filling in the main information in the OVL template. It also provides ready-made templates for creating an OVL virtual experiment with upload and publish SWF simulation. In addition, it provides students with the functionalities to create quizzes and discussion forums in the OVL.

#### **Instructor management**

These two tools offer an instructor management functionality in the instructor mode of the VLP, which gathers all the OVLs that were designed and produced by students as learning outcomes in the VLP.

### 2.2. OVL course as learning materials

In order for the educational technology students to know how to design and produce an OVL, we developed special course contents presented by the VLP. The contents consist of three units with 11 lessons including multimedia elements like text, video, and instructional drawing and images, as shown in Fig. 2. The first unit represented some information and knowledge about virtual laboratory as a modern technology tool, especially, the concept and advantages of OVLs, and general design of an OVL. The second unit focuses on the design of an OVL as an instructional product. The third unit explains standard skills for producing simulations in virtual experiments using Adobe Photoshop, Animate CC and ActionScript 3.0 on the OVL creator tool.

### 2.3. Learning process with the VLP

Fig. 3 shows a typical learning process with the proposed VLP. First, students learn the course contents of the tool. Then, they participate in discussion forums for the course

topics using the forum tool at the end of each course unit. Next, they make a design for their own OVL in a specific subject using the OVL designer tool at the end of the unit two. Finally, they produce a simulation for virtual experimentation using Adobe Photoshop, Adobe Animate CC, creating a unique OVL product by the OVL creator tool. The students received online responses as a formative evaluation to get immediate feedback on their performance during their learning with the VLP.



Fig. 2. A screenshot for course contents

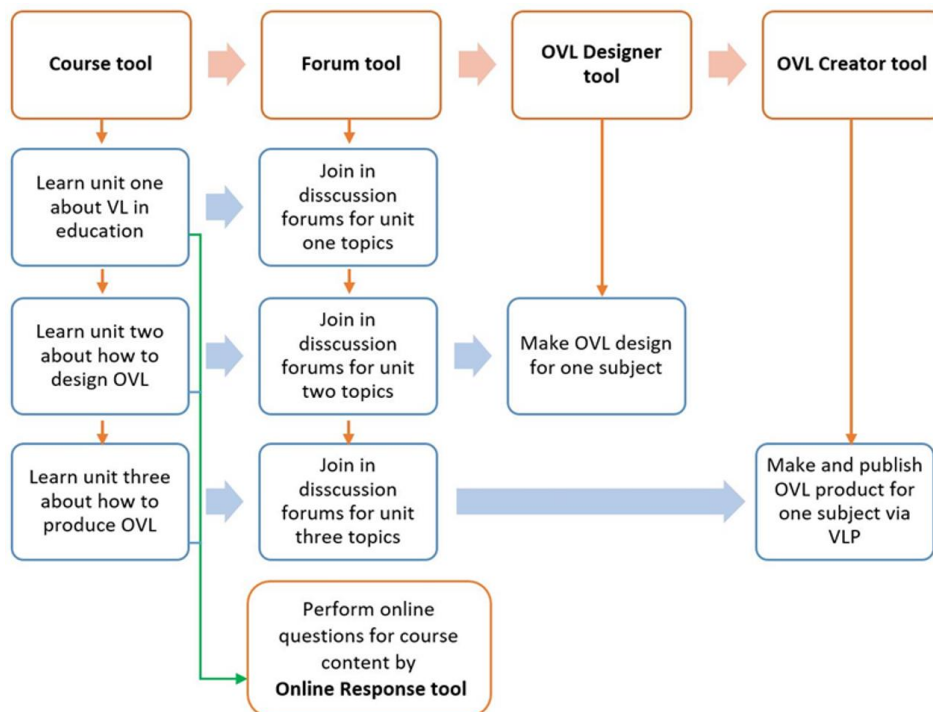


Fig. 3. Major tools for learning with the VLP

#### *2.4. Difference from existing LMSs*

While there are many different open source learning management systems (LMSs) related to the VLPs available today such as Moodle and Sakai, we developed a new VLP without adopting anything from existing open source LMSs. In comparison with other existing LMSs, the developed VLP includes unique features. Existing LMSs generally do not involve specialized tools related to designing and producing OVLs; our VLP contains new functional tools such as the OVL designer tool and the OVL creator tool enabling educational technology students to develop their own OVLs. Besides, the VLP has specialized course contents for teaching OVLs to students. Although both LMSs and the VLP include tools for developing courses, the course tool in the VLP has an entirely different user interface and content presentation. The VLP also provides a new tool which enables instructors to conduct online formative evaluations. Existing LMSs have several useful tools such as portfolio, workshop, and podcast that the VLP does not include, but we decided to develop our own VLP to reduce complexity in designing and producing OVLs as much as possible.

### **3. Methodology**

In order to overcome the lack of skills of the educational technology students, the main experiment was performed to examine the actual impact of the proposed VLP in cultivating the target skills of designing and producing an OVL.

#### *3.1. Participants*

The participants of this research were thirty undergraduate students (4 males and 26 females) who were in the fourth grade of the faculty of specific education at South Valley University, Egypt. They were majoring in educational technology and ranged in age from 21 to 24 (Mean = 21.7, SD = 0.65). All of them were assigned to one experimental group. They took part in a class with the VLP in the second term of the academic year 2015-2016 and were taught by the same instructor. This research took into account the ethical consideration during this implementation. The formal permission to conduct the experiment was received from the head of the educational technology department and dean of the faculty of specific education. Moreover, prior oral consent was obtained from the students in participating in the experiment. The experiment focused on an educational domain and did not have any harmful effects mentally and physically.

#### *3.2. Instruments*

We adopted four types of evaluation instruments to collect data during the empirical experiment. One external specialist in the educational technology field reviewed and validated all the evaluation instruments. To confirm the test-retest or inter-rater reliability for these instruments, we also conducted a pilot study with ten students:

- a) An online achievement test: It measured the level of attainment of knowledge in designing and producing OVLs. It consisted of 20 single choice questions (three options) with a total score of 20. Test-retest reliability measured by the pilot study was 0.705 as Pearson correlation. The VLP automatically calculated the results of the test. The relative weights of the course topics were taken into account when preparing the test questions. The objective of the test was

allocated to achieve 80% of knowledge about designing and producing OVL as the mastery level. The item example of the achievement test is “*To upload interactive simulation files of the virtual experiment in the VLP, the file extension format must be... (psd - fla - swf).*”

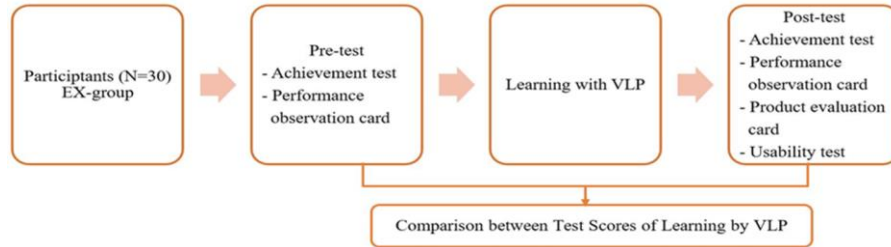
- b) An online performance observation card: It measured performance level of educational technology students in designing and producing OVLs. It included 34 skills with three rubric subscales (Performing skill with high level = 2, Performing skill with moderate level = 1, No performing skill = 0). The total score of the card was 68. The inter-rater reliability was used to check the reliability of the online performance observation card. The two raters observed and estimated these skills for each student in the pilot study at the same time. The Mean of the inter-rater reliability percentage was 96%. This value points out the acceptable reliability of the online performance observation card. The goal of the card was to reach 80% as the mastery skills. One of the researchers observed and estimated students’ skills based on the rubric scale before and after learning with the VLP. The results were automatically calculated by the VLP. The item example of the online performance observation card is “*Creating a virtual experiment in the OVL.*”
- c) An online product evaluation card: It measured the effects of the VLP in enhancing the production skills of OVLs for educational technology students. It included 23 criteria with three rubric subscales (Available = 2, Somewhat Available = 1, Not available = 0). The total score of the card was 46. The pair raters evaluated and estimated these criteria for each student in the pilot study at the same time. The Mean of the inter-rater reliability was 99% in the case of the pilot study. The result shows the logical reliability of the online product evaluation card. The card aimed to achieve 80% as the mastery criteria. One of the researchers evaluated each OVL product by the students based on the rubric scale after learning with the VLP. The results were calculated by the VLP. The item example of the online product evaluation card is “*Simulation of each virtual experiment in the OVL was working interactively.*”
- d) An online usability questionnaire: It was composed of nine closed items with 5 Likert scale from 1 (strongly disagree) to 5 (strongly agree). The usability questionnaire items for the VLP were proposed and derived based on previous scales of usability (Lund, 2001; Nielsen, 1994). All questionnaire items were formulated in positive design.

### 3.3. Experiment procedure

A quasi-experimental research design with one group pre-post test was adopted. A computer lab with internet connection at the university was provided to the participants as a place to attend the experiment. The Arabic version of the VLP was used in this experiment. Before starting, an orientation session was conducted to share the purpose of the research. The participants were registered as users in the VLP. Each of them accessed the tools and the contents on the VLP website with username and password. Next, the pre-test instruments - the online achievement test and the performance observation card - were applied to assess the initial level of knowledge and skills in the design and production of OVLs of the participants. The participants were then asked to learn by the proposed VLP with the instructor in the computer lab. The participants followed the main



process as explained in Fig. 3. Finally, after finishing their learning with the VLP, the participants were asked to conduct the post-test instruments including the achievement test, the performance observation card, the product evaluation card, and the usability questionnaire. The evaluation procedure is shown in Fig. 4.



**Fig. 4.** An evaluation procedure

The main role of the instructor during the learning process with the VLP in the computer lab was to provide responses to student inquiries related to the learning contents of how to design and produce OVLs. In addition, the instructor asked students to answer online electronic questions by an online response tool as formative evaluation during learning with the VLP.

#### 4. Results and discussion

##### 4.1. Knowledge of designing and producing OVLs

A paired-sample t-test was performed to compare the scores of the thirty participants in the achievement test before and after learning with the proposed VLP. As shown in Table 2 and Fig. 5, the results indicated that the scores on the post-test ( $M = 18.73, SD = 1.55$ ) were higher than the scores on the pre-test ( $M = 12.37, SD = 4.27$ ),  $t(29) = 7.832, p < 0.01$ , Cohen’s  $d = 1.43$ .

**Table 2**

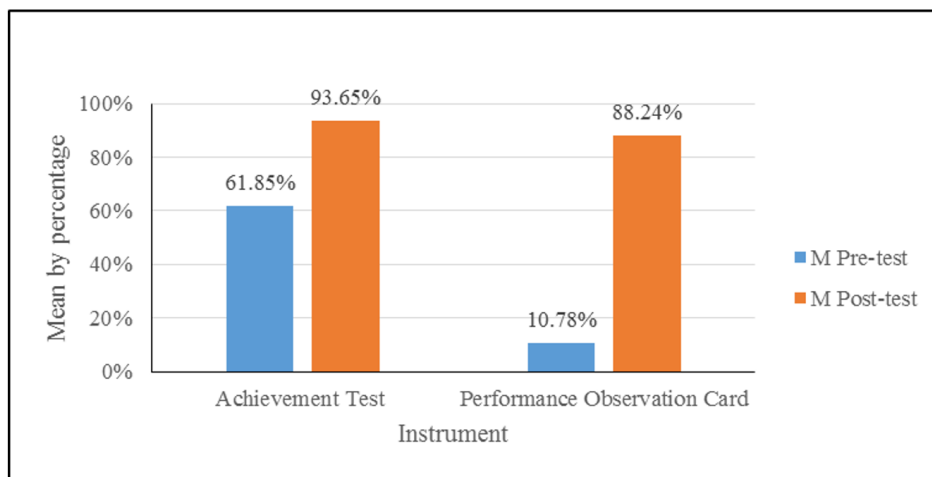
Results of the pre- and post-test of the achievement test and performance observation card

Evaluation Instrument	Group	N	Mean	SD	DF	T-Value	<i>p</i>	Effect size (Cohen’s <i>d</i> )
Achievement test	Pre-test	30	12.37	4.27	29	7.832	.000*	1.43
	Post-test	30	18.73	1.55				
Performance observation card	Pre-test	30	7.33	7.17	29	24.640	.000*	4.50
	Post-test	30	60	9.38				

*Note.* \* $p < 0.01$ ; Achievement test full mark score =20; Performance observation card full mark score =68

These results showed a significant difference at 0.01 level with the effect size exceeding Cohen’s convention for a large effect ( $d = .80$ ). Thus, these results suggested the VLP treatment had enough of an effect on developing the knowledge of designing and producing OVLs of the educational technology students. The proposed VLP delivered the interactive learning environment to the participants in various ways. First, it

provided the participants with special multimedia online course contents including video and instructional image/drawing, which covered knowledge of designing and producing OVLs. Second, the VLP provided them with discussion forums for the topics relevant to designing and producing OVLs. Third, it enabled them to receive immediate feedback about their performance through online responses as the formative evaluation. Fourth, it supported diverse types of web form such as assignments and simple web quests, to provide deep understanding of the learning topics. Finally, it gave the participants sufficient training opportunities to learn the skills in designing the OVL with the OVL designer tool and the skills needed to produce the OVL with the OVL creator tool. The results in Fig. 5 show that the Mean percentage ratio of post-test results in the achievement was over 93%. That indicates that the proposed VLP has enhanced mastery of learning knowledge for the participants at the level of over 80%.



**Fig.5.** Comparison between Mean of pre- and post-test of the achievement test and performance observation card

#### 4.2. Performing skills of designing and producing OVLs

A paired-sample t-test was also performed to compare the scores of the thirty participants on the performance observation card before and after learning with the proposed VLP. As shown in Table 2 and Fig. 5, the results indicated that there was a significant increase in the scores on the post-test ( $M = 60$ ,  $SD = 9.38$ ) over the scores on the pre-test ( $M = 7.33$ ,  $SD = 7.17$ ),  $t(29) = 24.640$ ,  $p < 0.01$ , Cohen's  $d = 4.50$ .

These results show a significant difference at 0.01 level with the effect size exceeding Cohen's convention for a large effect ( $d = .80$ ). Thus, these results illustrated that the VLP treatment had a notable impact on developing the performance of the designing and producing OVL skills of the educational technology students. The VLP supported the participants with the course contents, which showed the designing and producing OVL skills, especially in the form of instructional videos for the specific skills. The VLP also provided the OVL designer and the OVL creator tools as the specialized innovation tools with the ready-made templates for learning the design and production of OVLs without programming knowledge. The results in Fig. 5 show that the Mean percentage of the post-test of the performance observation card was over 88%. These results indicate that the VLP helped the participants by conducting suitable training.

4.3. Producing skills of the OVL

A criterion of the mastery level of 80% was applied to the scores of the 30 participants on the product evaluation card after learning with the proposed VLP. As shown in Table 3, the results of the post-test range from 40 to 46 (the full mark was 46). Thus, we confirmed that all the participants’ scores were higher than the assumed criterion 80%. Moreover, the Mean of the correct percentage of the product evaluation was over 95%, which was higher than the original mastery level. This demonstrates that the proposed VLP has the potential to enable students to reach the mastery level in producing the OVL.

**Table 3**

Results of the participants' scores of the product evaluation card

Research Instrument	N	Min	Max	M	SD	Criterion Score of mastery level 80%
Product Evaluation Card	30	40	46	43.97	1.43	36.8

The results infer that the interactive learning contents and ready-made templates of the OVL creator tool caused the effectiveness of the VLP. The VLP provides learning contents with instructional videos for the OVL producing skills and discussion forums to enhance the learning process of the OVL producing skills. The VLP also assisted the students by helping them receive and download learning files related to the learning contents of producing OVLs, for example, a file on how to create an OVL forum. It provided the students with an online formative evaluation prepared in advance, which led to supporting the learning of the target contents. It enabled the participants to carry out enough training to produce and manage their OVL products by the OVL creator tool. Finally, the OVL creator tool provided the participants with a common, ready-made template for establishing and publishing an OVL framework as shown in Fig. 6. This tool automatically displayed a simple OVL platform, including several OVL function tools with common design elements for ready-made templates such as adding a virtual experiment, adding a forum, adding a quiz, and OVL reports. Thus, the VLP provided the participants with specialized OVL tools for creating and displaying OVL components, which assisted them in producing the OVL products in multiple domains without requiring knowledge of coding.



**Fig.6.** The ready-made template for creating an OVL framework

The domain classification of the produced OVL is described in Table 4, which shows the number of products for each domain. The number of the OVLs as final products were distributed to the eight domains (subjects). Although 21 (70%) of the products were related to science fields such as biology, chemistry, geology, and environmental sciences, the remaining 9 (30%) were in other areas including social studies, computer networks, mathematics, and Arabic language. This diversity indicates the proposed methodology is an acceptable alternative to real laboratories not only in science fields, but also conceptualized subjects.

Table 5 shows the number of the produced OVL products per educational stage covering kindergarten to university level material. We can conclude that the proposed VLP facilitates the design and production of OVL products for a variety of domains and educational stages with appropriate contents and functionality. Due to the limitation of the experiment, it is difficult to show actual coverage for our proposal. We will continue the research to investigate this point.

**Table 4**

Classification of the number of the OVL products by subject domain

Domain name	Science	Social Studies	Arabic Language	Biology	Chemistry	Computer Network	Geology and Environmental Sciences	Mathematics
Number of the OVLs products	14	2	1	5	1	4	1	2

**Table 5**

Classification of the OVL products by educational stage

Educational stage	Kindergarten stage	Elementary stage	Preparatory stage	Secondary stage	University stage
Number of the OVLs	1	10	8	5	6

#### 4.4. Usability of VLP

Table 6 shows the results of the 5-point Likert-scale questionnaire with nine question items. Almost all of the participants responded positively (strongly agreed) to the usability of the VLP software. General approval by the participants is indicated by the overall Mean = 4.62.

At the end of the empirical experiment, the participants were asked to respond one open-ended question via the VLP forum tool. The question was “What is your opinion of the VLP for designing and producing OVLs?” We received 27 participant responses. Most of the participants shared the opinion that the VLP is a good solution for developing skills in designing and producing OVLs. The main positive comments related to the good and flexible design of the VLP. There was also positive feedback about the VLP being easy to use and navigate; the VLP having specialized tools for creating OVLs in diverse

domains; the VLP providing theoretical explanations and videos of all the basic and professional skills of how to design and produce an OVL; and the VLP not requiring participants to have programming experience. Two participants reported negative feedback. One felt that the many steps and pages it took to create an OVL quiz was inconvenient. This participant also stated that the user interface of the VLP had a nice design but that the other pages did not have the same design. The only other negative feedback came from another participant who stated that the explanation of the video did not include sound in the VLP.

**Table 6**  
Usability testing questionnaire results for the VLP

Questions	Responses (Number of Students)					Mean
	SA	A	N	D	SD	
Q1 The user interface of the VLP was acceptable and attractant.	22	6	1	1	0	4.63
Q2 It was easy to design, produce, and publish the OVLs using the VLP.	22	6	1	1	0	4.63
Q3 The VLP provided a good electronic environment to learn additional courses in the future.	20	8	2	0	0	4.60
Q4 The VLP had flexible navigation to refer to the platform homepage from any pages.	23	4	3	0	0	4.66
Q5 The VLP showed error messages to fix any problems during learning in the VLP.	23	6	1	0	0	4.73
Q6 The VLP provided appropriate help and guidance.	17	9	4	0	0	4.43
Q7 A performance and efficiency of the VLP are acceptable.	20	8	2	0	0	4.60
Q8 The VLP provided enough management function regarding OVL design and management tools.	23	4	3	0	0	4.66
Q9 The aim of each tool in the VLP was clear and understandable.	19	10	1	0	0	4.60
Overall Mean						4.62

Note. SA(5) = Strongly Agree; A(4) = Agree; N(3) = Neutral; D(2) = Disagree; SD(1) = Strongly Disagree

### 5. Conclusion

In this study, we proposed that our VLP would enable educational technology students to design and produce OVLs in a consistent way. The term “consistent” means the fixed templates, components, and presentation in various virtual laboratories with different domains. The participants in the study were 30 students interested in integrating ICT in education. For the RQ1, the results showed a statistically significant impact of the VLP in

increasing learning outcomes of these students for designing and producing OVLs. In other words, the VLP had a considerable effect on producing the OVL products in several fields and educational stages with the expected skill level. For the RQ2, the results also confirmed that the participants had a positive attitude towards the VLP, with nearly all considering the VLP as a positive solution for teaching the skills of designing and producing OVLs. The proposed VLP was presented to students in educational technology departments as a new specific tool to enable them to design and produce OVLs as a modern ICT technology to improve education.

Next steps for the VLP consist of further design and functionality enhancements to the VLP followed by additional testing. We plan to update the OVL design and OVL creator tools with a better ready-made template for designing and producing virtual experiments, including simulations and video functionality. In addition, the graphical user interface of the VLP will be redesigned by grouping similar tools into one category. Some new features will also be added. When complete, the latest version of the VLP will be examined again in developing the designing and producing OVL skills of postgraduate students.

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