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An Instructional Design Model and Criteria for Designing and Developing Online Virtual Labs

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ABSTRACT

The purpose of this work is to propose a general instructional design model to teach students in faculty of education, especially in department of educational technology how to design and develop online virtual labs in a common way. We have made analyses of previous instructional design models and related studies in regard to the virtual labs to specify diverse features of the proposed model. It was found that the online virtual labs have no conventional instructional design model, especially for designing and developing stages and also no common shape and components. Based on these results, we have reached to a new suggestion model which guides the students in refinement of the future learning environment using recent technology. In this paper, we also present a list of criteria for designing and developing the online virtual labs.as a modern principles for directing designing process of online virtual labs environments to become instructional products. We have made a derivation of these criteria from previous studies related to the virtual labs, e-Learning technologies and some miscellaneous technological resources in educational technology. These criteria would provide the students with educational and technological guidelines to produce the online virtual labs with high quality and efficiency.

KEYWORDS

Online Virtual Labs, Instructional Design Model, Educational Technology Students, Designing and Developing Criteria.

1. INTRODUCTION

In the 21st century, technological revolution had made a great positive impact on diverse fields including education. Therefore, ICT became one of the main elements of any educational systems/curriculums nowadays. This impact led to the emergence of the many applications of technology in education, such as e-learning, distance learning, virtual learning, and virtual campus/classroom. Some educational systems have expanded in using e-learning at current schools and universities because e-learning has a potential for overcoming individual differences among learners and for providing them with learning environments anytime and anywhere.

Virtual labs (VLs) are one of the important learning applications in developing modern education. The VLs work as an alternative solution of real labs since the VLs have few restrictions about equipment, cost, and risks of experiments. In addition, the VLs provide the learners with sufficient training opportunity for the experiments because of time and economic efficiency. In recent studies, the VLs have gained considerable attention in improving education, especially in supporting practical learning. Chu [1] claimed that the VLs provided simulations of complex scientific processes that were less likely to be demonstrated in the real lab. Furthermore, Tatli and Ayas [2] confirmed the VLs enriched the learners' experiences as a supportive factor to the real labs. On the other hand, many previous studies have proven the important impact of the VLs on learning practical "skills" in various fields such as chemistry [3], computer network [4], medicine [5], mathematics [6], and so on.

From these previous researches, the VLs lead to mastery and creativity in learning by providing interactive virtual environments, which make the learners repeat diverse activities for improving their skills and for conducting their experiments with saving costs and full control in experiment variables. In addition, we can now use the VLs for theoretical fields that have no labs in the reality by experiencing a new simulation to understand difficult concepts and relationships. If we intend to teach geography of climate and weather practically, for example, we can use the VLs including a simulation in regard to changes in temperature on the map.

In order to improve modern education by using such new technology, who should be responsible persons? One of the candidates would be students

in faculty of education, especially in department of educational technology. Because these students should have potentials for implementing such technology in the future schools and universities. Besides, their academic programs in their universities usually contain diverse ICT courses which show them how to integrate modern technology in coming education. Consequently, such students have to develop their skills in designing and developing the online virtual labs, we call it DDOVLs, for the era of e-learning and virtual learning. However, now they may have no instructional design models which guide how to design and develop the online VLs because most of the previous studies about the VLs focused to establish the effectiveness of the VLs in specific fields as new tools in education.

In this paper, we suggest an instructional design model to teach DDOVLs to the students in the department of educational technology and in the faculty of education through uniform shape and components. This model would enable them to reach suitable skills for DDOVLs at any courses and fields in the future schools and universities. In addition, we present a list of criteria to provide guidelines of DDOVLs for the students as an initial teaching tools for the proposed model. We have made a derivation of the criteria, which consist of objectives, contents, learning activities, evaluation, feedback, platform, multimedia elements, simulation, administration, navigation, interactivity, publishing, and technical support from literature reviews of the recent previous studies in regard to the VLs and e-learning, previous criteria of designing online courses, and websites.

This paper is ordered as follows. First of all, we describe target students as next responsible persons for our DDOVLs model. And then, we discuss a general definition of the VLs and the online VLs without domain restrictions in section 3. After that, we claim support factors and advantages of the OVLs in section 4 and 5. In section 6, we describe required tasks for teachers and learners in using the OVLs in the classroom. In section 7 and 8, we propose an instructional design model and suggest a DDOVLs criteria to teach DDOVLs. We finally conclude our paper and explain future work in section 9.

2. TARGET STUDENTS

Online virtual labs (OVLs) are new web-based technology in improving modern practical education. Therefore, most teachers and instructional designers in the current school may grope for a way to integrate such technology into daily teaching and learning. This makes the main targets of our research two types of the students as the next generation of specialists and responsible persons for ICT in education.

2.1 Students in Department of Educational Technology

The students in the department of educational technology typically learn how to integrate ICT in education, according to educational theories, instructional design, and other perceptions of educational sciences. The range of their learning usually covers designing, developing, utilizing, and evaluating technological resources, such as e-courses, instructional websites, interactive videos, digital images and graphics, and educational software. Therefore, these students have potentials to be responsible for implementing such technology in the future schools after graduation as instructional designers, content developers, ICT teachers, and specialists for educational technology.

2.2 Students in Faculty of Education

Most of the students in the faculty of education will become teachers who specialize in one subject like chemistry, physics, mathematics, geography, English and so on. The range of their learning mainly covers traditional pedagogy with their specific fields. However, they are also requested to understand the advantage about implementing ICT in education as next generation teachers. Therefore, these students will take an important position for utilizing such technology to the future classroom.

3. GENERAL VLs

3.1 General Definition of VLs

In an effort to teach the VLs to the students in the department of educational technology and in the faculty of education, we first need to consider about a general definition of the VLs because they should learn basic concept of the VLs without any domain restrictions.

The definitions of the VLs in some literatures have been limited as a substitute for the real labs. Babateen [7] stated the VL is “a virtual studying and learning environment that stimulates the real

lab. It provides the students with tools, materials and lab sets on computer so as to perform experiments subjectively or within a group at anywhere and anytime". Harms [8] also defined the VL as "a computer simulation which enables essential functions of laboratory experiments to be carried out on a computer". In addition, Carnevali and Buttazzo [9] referred to the VL as "a computing system that allows to share the physical resources available in a laboratory with remote users connected on the internet". On the other hand, it was clear the difference of the VLs' form in the previous studies. Harms [8] focused on "a computer simulation", Carnevali and Buttazzo [9] represented "a computing system", and Prieto-Blázquez et al. [10] referred to "virtual learning environment".

Based on the above discussion, we define VLs are virtual learning and teaching environments designed and developed by means of the instructional design models. In the VLs, the learners interact with diverse kinds of learning methods such as excises, practices, activities and simulations to reach the learners' goals such as mastery of a specific skills and understanding of relationships among concepts anytime and anywhere.

3.2 General Design of Online VLs

In this section, we discuss about the general elements of the VLs such as their shape and components to reach to one uniform of the "online" VLs (OVLs). The OVLs become now one of new tools in developing education to enhance online courses in any schools and universities. Therefore, such uniform would be suitable for teaching the virtual points in the OVLs to the students.

In order to consider the uniform of the OVLs, we have made an analysis of many fields of the previous studies which proposed not only online but also computer-based VLs such as science [11], chemistry [3], [12], biology [13], physics [14], medicine [5], psychology [15], mathematics [6], calculus [16], computer science [17], automatics and robotics [18], computer network [4], [19], software engineering [20], computer interface technology [21], linguistic [22], studio [23], history and cultural dynamics [24], statistics [25] and others. After analyzing these previous studies, we summarized the following results:

1. The significant impact of the VLs technology was to increase learning skills and educational attainment of the learners in the various fields.
2. The VLs are suitable for teaching courses which have the real labs and have no lab in the reality.
3. There was no fixed form in designing of the VLs.
4. Components and way of organizing contents in the VLs differed on each previous study.
5. The VLs were divided into two types, OVLs and computer-based VLs.

Here, we first make clear the differences between the two types of the VLs as follows.

OVLs: This type of the VLs provides virtual environments in the form of the website via the internet. Therefore, the learners can learn skills, experiments and theoretical ideas about the courses practically anytime and anywhere. In addition, they interact with not only the contents through interactive simulation, but also the teacher and their colleagues. Such OVLs also provide them with many information offered by external website links.

Computer Based VLs: This type of the VLs is available in the form of specialized software which contains menus and tools in a specific field. After setting up the VL program on the computer, the learners can conduct experiments to obtain practical skills. This type sometimes needs a lot of time in designing and producing the program package and is now limited to specific practical fields, for example, ChemLab [26], Crocodile Physics [27], and Virtual Chemistry Lab Program [28].

From the results of the analysis, we decide to suggest a unique and general form of the OVLs suitable to any courses/domain (not only practical but also theoretical) in educational institutions. Our suggestion is divided into the following two parts:

Fixed part: We call it OVL platform. This part is stable in any OVLs. It consists of common functions such as basic user interfaces to display any virtual experiments from any courses, management tools like login, tracking, and communications tools such as e-mail, forum, chat, and video conference.

Variable part: We call it OVL content. This part is variable according to the contents of the courses. In this part, we suggest how to organize the contents inside the OVLs to become segments.

Each segment should belong to one experiment, which consists of educational objectives, theoretical explanation, instructions and procedures, simulation, activity, evaluation, and summary.

Such form of the general OVLs would help the students for designing and developing the high quality OVLs in a stable way.

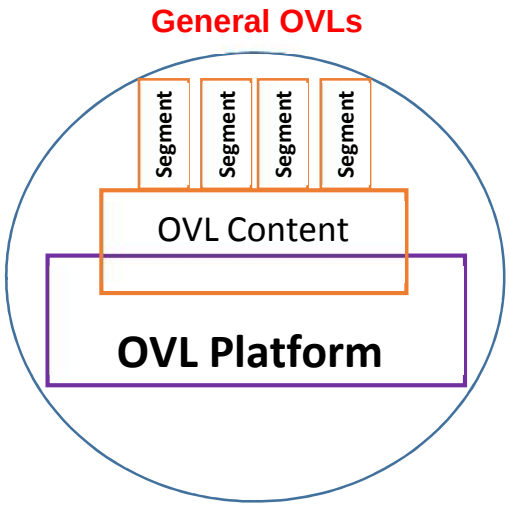

Figure 1. Suggestion form of general OVLs

4. OVLs SUPPORT FACTORS

4.1 OVLs as Supportive Tools for Online Courses

The OVLs and online courses are similar in presenting something to the learners via the internet in an easy and interactive way. However, the types of these contents are quite different. The online courses typically provide e-contents with multimedia. On the other hand, the OVLs mainly serve interactive simulations for practical experiments. It means the OVLs would enhance the online courses from practical point of view. In order to expand the availability and reusability, we sometimes implement both materials independently. We can also integrate the OVLs environment into the online courses as complementary learning resources.

4.2 OVLs as Enhancement Tools for Learning inside Real Labs

Another role of the OVLs is to increase levels of learning in the real labs. We previously claimed that the OVLs are sometimes used in blended learning where the learners can make training before and after experience in a real lab [29]. On the other hand, they may be able to learn new simulation which has no real lab. In both ways of learning on the OVLs, they have to pass the following several steps in order to learn the contents deeply.

Firstly, the learners should identify general and specific objectives in the OVLs and know the theoretical background about simulations through briefly text information and instructions about how to perform the practical simulation in the OVLs without mistakes. And then, they begin to conduct simulation practically through many actions such as dragging and dropping items, changing values and shapes, collecting, arranging, and classifying items. They may also communicate with other learners with diverse synchronous and/or asynchronous tools to confirm their achievement and skills. Finally, they have to make a self-evaluation through answering electronic questions and read a summary about main information of the target simulations to conclude the contents.

The following figure shows these cyclic steps of the idealistic learning process inside the OVLs. If the learners do not acquire the target skills, they can repeat learning from the Objective stage. As a result of the learning process, they would reach to the following outcomes:

1. Sufficient training about practical skills.
2. Learner's experience related to the real labs' equipment.
3. Learner's experience related to the virtual learning environment tools.
4. Mastery of learning by training and experiencing difficult theories practically.
5. Implementation of new ideas during learning.

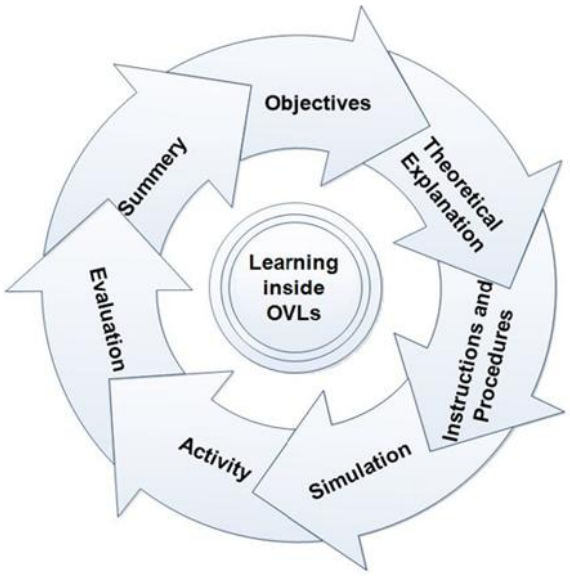

Figure 2. Idealistic Learning process inside OVLs

5. ADVANTAGES OF OVLs

The OVLs are characterized by many advantages as modern methods in developing educational process. Some previous studies presented diverse advantages of the VLs such as [3], [30], and [31]. Now we have organized and added these advantages from improvement of learning point of view as follows:

1. Economic: The OVLs are low in costs of equipment and tools because of the virtual form as well as of maintenance compared with the real labs.
2. Richness: The OVLs enable to have rich environments with the kits and tools, furthermore with information through linking to especial websites.
3. Safety: The OVLs provide safe experimental environments, especially with regard to the danger and harmful experiments.
4. Sufficiency: The OVLs supply sufficient and repeatable training environments for experiments like 'learning by doing', which lead to mastery in learning.
5. Consolidation: The OVLs help the learners in improving their performance in terms of experiments, equipment, and tools in the real labs.
6. Motivation: The OVLs cause excitement in learning to the learners by interactive simulation about reality and theoretical ideas, which encourage to continue their learning process.
7. Understanding: The OVLs facilitate the learners to reach a high level of understanding especially in practical experiments, concepts, laws, rules, relationships, processes, and ideas in various courses, which leads to improve learning.
8. Interactivity: The OVLs serve interactive environments to the learners with not only the OVL contents, but also the teachers and other learners.
9. Accessibility: The OVLs provide diverse contents to the learners anytime and anywhere.
10. Creation: The OVLs offer possibility of original experiments by testing new variables on the virtual representation about some theoretical ideas, which conduce to creativity in learning.
11. Integration: The OVLs work to enhance the online courses through offering practical part of the course.

6. TASKS OF TEACHER AND LEARNER IN OVLs

6.1 Tasks of Teacher in Designing Process

In actual education systems, the teachers would have many tasks in the designing process of the OVLs as the content experts. In this section, we illustrate two types of the tasks by the teachers' responsibility. Some educational systems focus to qualify the teachers to specialize in one subject. In addition, these systems also produce specialists in educational technology to work together with the teachers in implementing technology in the schools. In these cases, the teachers play an important role in designing the OVLs regarding to their teaching courses. Therefore, they must be familiar with teaching strategies for e-learning and the technological ability. The main point of their role is to participate with specialists of educational technology in the following design steps:

1. They must decide target learners and courses.
2. They must specify teaching topics from the courses.
3. They must determine the general and specific objectives and formulate the objectives accurately.
4. They must identify the importance and necessity of the OVLs for the target.
5. They must prepare the appropriate contents and activities for the OVLs to achieve these objectives.
6. They should consider how to organize the topics logically.
7. They should select the suitable evaluation style for each topic.

The teachers in other educational systems may also have additional tasks in designing process to integrate ICT into the classroom in the absence of the specialists of educational technology in their schools. In these cases, they have to be responsible for not only designing and but also developing the OVLs besides teaching courses. We summarize such additional tasks as follows:

1. They must study and apply criteria for designing and developing the OVLs with high quality.

2. They must design and implement an OVL platform.
3. They must design and implement OVL contents.
4. They must publish the OVLs via the internet and conduct technical tests.
5. They should hold training to other teachers about how to use the OVLs.
6. They should conduct improvement of the OVLs in light of the evaluation results.

6.2 Tasks of Teacher in Teaching with OVLs

When using the OVLs in teaching, the teachers also face several tasks as follows:

1. They must plan online teaching to reach best practice.
2. They should encourage and motivate self-learning for the learners.
3. They should make training to the learners about how to use the OVLs.
4. They should plan to integrate the OVLs in the real labs.
5. They should interact with the learners via the internet in a synchronous or asynchronous manner.
6. They should evaluate and monitor the performance of the learners in order to continue for improvement of education.
7. They should provide enrichment activities with additional internet sites to get related information easily.

6.3 Tasks of Learner in OVLs

In using the OVLs in learning, the learners are required to pass the following tasks:

1. They must perform self-learning for the OVL contents according to their intentions and attitudes.
2. They must conduct the requested activities and assignments and send them to the teachers via electronic form.
3. They should contact with the teachers and other learners through e-learning technology such as e-mail, forums, chat, audio, and video.
4. They should expand creative thinking during their learning process to reach new relationships among the variables.

7. INSTRUCTIONAL DESIGN MODEL FOR DDOVLs

In order to develop the next generation teachers discussed in the above section, we suggest an instructional design model for DDOVLs to teach the students in the department of educational technology and the faculty of education how to design and develop the general OVLs suitable to any field. The model would guide them to good practitioners of the OVLs to improve education.

In order to reach to our suggestion model, we have made an analysis of diverse previous studies. Some of them confirmed the effectiveness of the proposed OVLs [5], [6], [11], [12], [13], [14], [15], [17], [18]. Others discussed the previous models of the instructional design such as ASSURE model [32], ADDIE model [33], Kemp model [34], Dik and Carey model [35], Stephen & Staley model [36], Gerlach and Ely model [37]. The results of the analysis are summarized as follows:

- The OVLs had no instructional design model specific in teaching how to design and develop them for the teachers/specialists in developing education, especially the students in the department of educational technology and in the faculty of education.
- Most previous models focused on the components of the phases of the traditional and computer-aided education. For example, educational software was not mentioned as the e-learning and virtual learning components, which now becomes an essential element of modern educational systems.
- A number of the previous models involved the following phases: analysis, design, development, and evaluation.

Consequently, we have decided to propose our original instructional design model for DDOVLs as described in Figure 3 because we believe it is necessary to become widespread of teaching DDOVLs in various educational institutions.

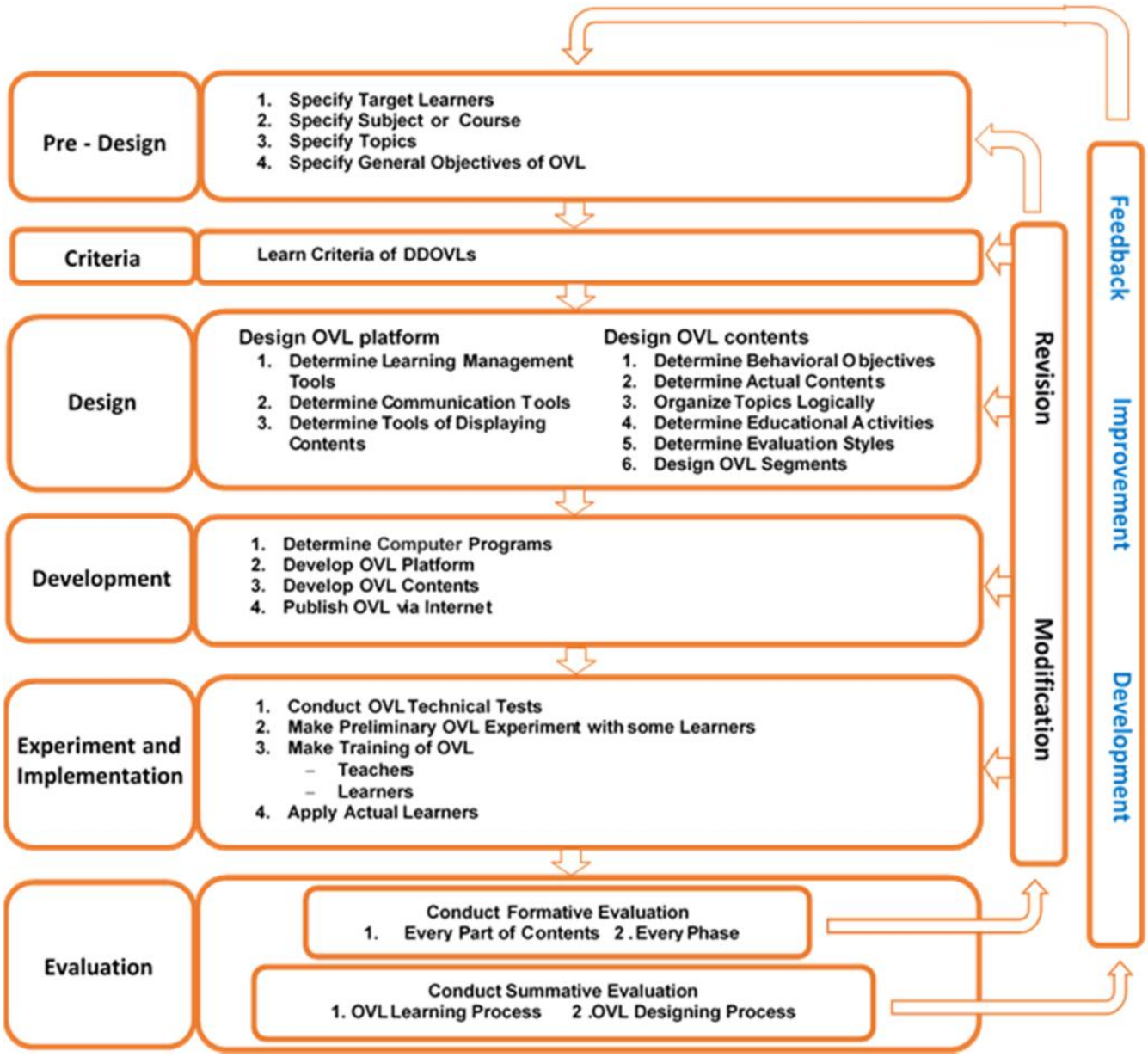

Figure 3. Instructional design model for DDOVLs

7.1 Pre-Design Phase

Pre-design is the first phase of the DDOVLs model where the students specify the target learners by determining the educational stage and grade like "3rd grade of elementary schools" or "freshman year of universities". Then, they select a target course and specify course topics that they intend to teach in the OVLs. Typically, they would pick up the topics regarding to not only recurrent training but also difficulty in understanding. Finally, they decide general objectives of the OVLs.

7.2 Criteria for DDOVLs Phase

The criteria are usually used to provide the guidelines for the students when designing and developing any technological tools for education. The students should learn the criteria to reach to acceptable educational and technological OVLs. Therefore, the professors of educational technology can prepare a list of criteria of DDOVLs or select any lists of the criteria prepared previously and teach it to the students.

7.3 Design Phase

The main role of the design phase is to provide the students with the sequential steps in order to reach general design suitable to any courses. As described in Section 3.2, we propose in this paper a new shape of the OVLs by dividing into the following two parts.

7.3.1 Designing OVL Platform

As we described the above, the OVL platform is the fixed and essential part in any OVLs. This part contains a group of tools which provides the learners with high interactivity during learning inside the OVLs. It also supports the teacher to manage learning and contents. It consists of the following elements:

a) Determine Learning Management Tools

In this step, the students specify some tools to manage learning inside the OVLs. The following tools are typically used in the OVLs:

- A registration tool which controls the learners' entrance in the OVLs.
- A tracking tool which records the performance of the learners in the OVLs.
- A download tool which presents the learners important files for learning inside the OVLs.
- An announcement tool which provides the learners with important dates for sending duties, etc.
- A search tool which supports the learners to find additional information.
- An evaluation tool which presents the learners a couple of the types of evaluation.

b) Determine Communication Tools

Communication is one of the important parts in learning on the OVLs because the learners are able to obtain actual usage of the knowledge by communicating with the teacher and other learners. Thus, the students should determine suitable communication tools. Some of them are synchronized such as chat rooms or video/audio conferencing. The others are asynchronous like forums and e-mail.

c) Determine Tools for Displaying Contents

The contents are main components in the OVLs. Thus, they should be presented easy to understand. The students have to specify some tools to display the OVLs contents such as upload tools, glossary tools, and content update tools.

7.3.2 Designing OVL Contents

The OVL contents changeable according to the courses or the fields. In this part, the students in the department of educational technology need to cooperate with some experts like actual teachers. In the case of the students in the faculty of education, however, all designing process would be conducted by them. Consequently, we present how to design the OVL contents for both students through the following sequential steps:

a) Determine Behavioral Objectives:

The students divide the general objectives of the OVLs into sub-objectives called behavioral objectives. Each objective covers a certain topic inside the OVLs to be easily observed and measured.

b) Determine Actual Contents:

The students specify sufficient contents for each topic that they intend to teach in the OVLs. They also specify digital images and graphics, digital audio, electronic drawing, and video so as to achieve the learning objectives inside the OVLs simply.

c) Organize Topics Logically:

The students arrange the list of the prepared topics of the OVLs logically from easy to difficult or simple to complex.

d) Determine Educational Activities:

The students specify suitable activities for each topic in the OVLs. These activities enable the learners to confirm information, increase their motivation, and support critical thinking and problem solving.

e) Determine Evaluation Style:

The students determine appropriate evaluation style. The style should be suitable to each topic with observance diversity in evaluation styles. In addition, they also determine the evaluation style for the whole of the OVL contents.

f) Design OVL Segments:

We propose how to design the OVL contents through conversion of the OVL topics into segments. Each topic belongs to one experiment or other concepts, and should be matched by one segment as described in figure 4. Each segment should have a clear title and following tabs: educational objectives, theoretical explanation, instructions and procedures, simulation, activity, evaluation, and summary as follows.

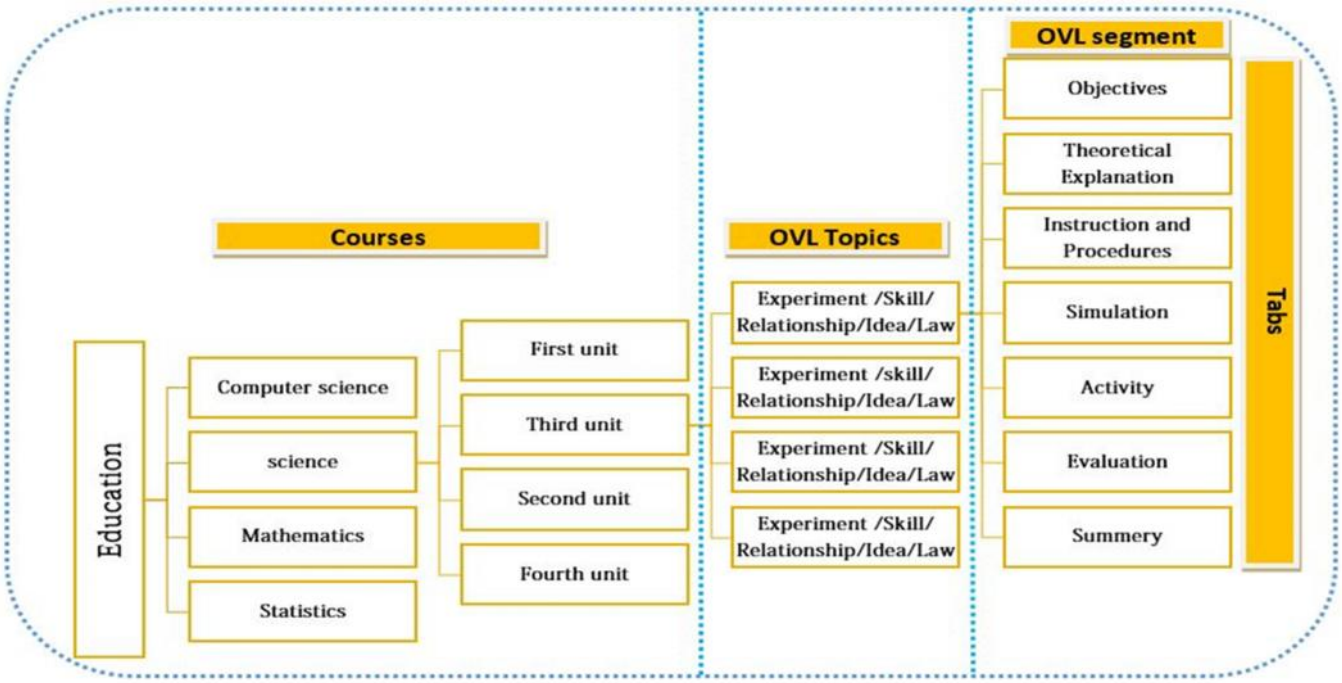

Figure 4. Organization of OVL contents

Educational Objectives: At first, the learners recognize the educational objectives that they should acquire at the end of learning for each segment.

Theoretical Explanation: In this part, the OVLs present the learners the theoretical backgrounds for each segment such as scientific laws, rules, and applications, information, and description.

Instructions and Procedures: This part explains the correct sequences to conduct the experiment in practice.

Simulation: It is a vital part as contained in the virtual components for the experiment in the form of images and animation, where provide the learners with practical implementation by dealing with several actions.

Activity: Each segment of the contents should include educational activities. Such activities enhance the learners' performance and conduce the improvement of learning outcomes and mastery of skills.

Evaluation: Each segment must contain the questions for self-assessment inside the OVLs. Such questions would confirm mastery of the contents and achievement of the objectives.

Summary: It must be placed at the end of each segment. It makes the learners summarize the main points in the OVL segment.

7.4 Development Phase

In this phase, the students begin to develop the OVLs with application development environments as the following steps:

a) Determine Computer Programs:

The students first select application development environments to realize the designed OVLs with high quality. The environments may support ASP, PHP, JAVA, MySQL, MSSQL, Adobe Flash, Cinema 4d studio, and Unity.

b) Develop OVL Platform:

After determining the environment, the students implement the OVL platform by programming the learning management tools and the display content tools inside the OVLs. In addition, they develop the synchronous and asynchronous communications tools.

c) Develop OVL Contents:

The students also produce the segments of the OVL contents such as texts, animations, image, graphics, video, simulations, electronic questions, and activities according to the DDOVLs criteria. They should keep the segments production to harmonize with the OVL platform.

d) Publish OVL via Internet:

The students specify name of OVLs website according to the instructional institutions and the course name. They also provide the necessary requirements about software and hardware on the server, such as capacity and security. Finally, they upload and publish the OVLs via the internet.

7.5 Experiment and Implementation Phase:

a) Conduct OVL Technical Tests

The OVLs after publishing become an initial instructional product. Therefore, the students should conduct technical testing such as interface and accessibility, navigation, robustness, database connection, and performance. Based on these results, they should fix the technical errors of the initial OVLs.

b) Make Preliminary OVL Experiments with some Learners

The students perform a preliminary experiment of the OVLs to a few learners in order to receive early feedbacks in regard to easy handling, difficulties, notes and mistakes. In light of the results, we can make necessary reforms and become a final version of the OVLs.

c) Make Training of OVL

Training on how to use such new technological resources contributes to increase the OVLs efficiency. Thus, they conduct training for the teachers about how to use the tools and functions and online teaching skills, and preform training for the learners about how to access, navigate, use the tools and functions, and to conduct their assignments electronically.

d) Apply Actual Learners

In this step, the teachers can use the OVLs actually in teaching in their classrooms as an instructional technology tool to start an online teaching session with the learners, to make discussion, to present replies for the learner's inquiries, to receive assignments from the learners, and to offer feedbacks from the performance of the learners.

7.6 Evaluation Phase:

Evaluation phase presents the students main indicators about learning inside the OVLs and quality of the designing process as a whole of the OVLs. They need to make improvements permanently in systematic process based on the results of the evaluation. At this phase, they would use two types of evaluation.

7.6.1 Conduct Formative Evaluation

– **Formative Evaluation for Every Part of Contents**

The teachers conduct a formative evaluation during the actual learning process inside the OVLs.Therefore, they should implement it as electronic questions and questionnaires in every segment of the OVL contents. The results of this evaluation provide the following feedbacks with regard to: revisions and modification of the OVL contents to the students, the learners' progress in achieving the objectives inside the OVLs to the teachers, and the level of performance to the learners in order to motivate them in continuing in their learning process.

– **Formative Evaluation for Every Phase**

The students also perform a formative evaluation after each phase during the design process under supervision of the educational technology professors to improve the DDOVLs model. They can use some tools such as evaluation forms, reports, and checklists. Figure 5 shows an example of the evaluation form for "design" phase.

7.6.2 Conduct Summative Evaluation:

– **Summative Evaluation for OVL Learning Process**

The students conduct a summative evaluation at the end of learning, which provides one of the main indicators about the learning process, the learners' level, and teachers' performance inside the OVLs. They can use some evaluation tools such as electronic tests and questionnaires.

– **Summative Evaluation for OVL Designing Process**

The students need to detect the negative and positive aspects of the whole of the DDOVL model at the conclusion of the project. They use some evaluation tools like evaluation forms, questionnaires and interviews with the teachers and the learners. They carry on such evaluation under supervision of the educational technology professors. The results would improve the OVL design process continuously.

Design OVL platform

OVL learning management tools			OVL communication tools			OVL displaying content tools		
Name of tool	**Function**	**Description**	**Name of tool**	**function**	**Description**	**Name of tool**	**function**	**Description**
Registration tool	*Enable learner for access to OVL*	*As form contains main information for learners such name of learner , student number , grade , email , username , password*	*Forum tool*	*To enable learners to make asynchronous discussion with teacher and other learners*	*Simple Forms to adding and reply for discussion topics contain this fields : subject of OVL discussion and write a message ,*	*Upload tool*	*Upload OVL contents*	*As form linked to database consist of this fields : name of file , upload OVL files include browsing button , upload button*

Design OVL content (course of chemistry)

Segment number	Title	Educational objectives	Theoretical explanation	Instructions and procedures	Simulation components	Activity	Evaluation	Summary
Segment (1)	*Preparation of nitric acid*	***At the end of this experiment the learner is able to:*** *[1]. recognize the components of a preparation of nitric acid [2].Implement the experiment of preparation nitric acid [3]. recognize the chemical*	***Chemical symbol for nitric acid is HNO3*** *Chemical properties of nitric acid* ***[1].Action of heat :*** *decomposes by heat giving brown fumes of nitrogen dioxide* $4HNO_3 \xrightarrow{\Delta} 4NO_2 + O_2 + 2H_2O$ ***[2]. It is oxidizing agent:*** *because oxygen gas evolved as a result of is*	***Steps to implement the virtual experiment*** *1.Drag the Bunsen burner and put it on the table 2.Drag the stand and put it next to the Bunsen burner on the table 3.Drag the retort and put it on stand above the Bunsen burner 4.Drag the pot which containing cold water to the table*	***A. Select images and graphics to design simulations are as follows:*** ***1. Images / graphics for lab – table of experiments*** ***2. Images / graphics of the necessary lab tools for experiment with state the name of each tool:*** *Retort - Bunsen burner - Stand -*	***Prepare an electronic report about:*** *•How to prepare nitric acid •Chemical properties of nitric acid •Uses of nitric acid in the life* ***Note: send the report to***	*Choose the correct answer 1. Nitric acid can be prepared by adding potassium nitrate to…… has a concentration under the temperature less than 100 ^{0}c (Sulfuric acid - hydrochloric acid Acid)*	*Nitric acid is transparent liquid without a colorless. Resulting from the interaction between potassium nitrate and sulfuric acid has a concentration in temperature of*

Figure 5. Formative evaluation Form for design phase

7.7 Features of DDOVLs Model

In the proposed DDOVLs model, we skip the analysis phase since the students in the department of educational technology and in the faculty of education do not need to make analyses before DDOVLs. First of all, analysis is a difficult phase since they need some experience in actual classroom. In addition, the target learners' characteristics are actually defined by the usual courses in the schools and universities. Our model also provides the teachers and the learners with enough technological training for using the OVLs. Thus, they do not need the learner and teacher analysis. The instructional designer and the actual teacher can specify the content parts like skill, idea, and experiment directly according to their experience in teaching the courses on the OVLs. It means they do not need course analysis, too. On the other hand, we add the pre-design phase as the first one. This would make good inputs for the designing phase. Our model also focuses on the criteria phase because the criteria are very important to guide them for DDOVLs with high efficiency. The professors of the educational technology can prepare or select any criteria in this phase.

We divide the design phase into two parts. The OVLs platform is a fixed part in any OVLs, which contains a group of tools to make management of learning and to provide the learners with multi communications with the teachers and the contents. On the other hand, the OVLs contents are variable parts according to the courses. The OVLs contents are divided into the segments, each of which belongs to one experiment, skill, or idea to improve learning. Such segments also have possibility for reuse in another OVLs. These parts would make the model general and suitable to diverse fields.

In the development phase, we do not specify application development environments to produce the OVLs so that they can select anything freely. In experiment and implementation phase, we claim two ways of experiment as the technical tests and the preliminary test. The results of the evaluation phase would make the students improve the OVLs in systematic process. Our model components in all phases offer the students the sequential steps to make them simple and effective.

8. SUGGESTION CRITERIA FOR DDOVLs

We also present a list of criteria for DDOVLs to be easier in teaching our model directly to the students. The criteria aim to reach modern educational and technical principles by providing guidelines. Consequently, we make a derivation of some elements of the criteria from the previous studies regarding to the VLs [38], [39], [40], [41], [42], [43], [44], and criteria for e-learning technologies, qualification, and evaluation [45], [46], [47], [48], [49], [50], [51], [52], [53]. In addition, other elements of the criteria are picked up from designing online electronic courses, developing e-contents, evaluating instructional websites [54], [55], [56], [57], [58], [59], and [60], and general aspects of educational technology [61], [62], [63], [64], [65], and [66].
Although there are diverse types of the previous studies, we divide the elements of the criteria into two parts as described in Table 1 so that they can understand the criteria easily. The one part is mainly related to educational rules and theories. Another part is technical rules related to the computer software. Our criteria contain diverse specific elements related to the OVLs. Thus, such elements are underlined in the following sections.

Table 1. Elements of criteria for DDOVLs

DDOVLs Criteria	
Educational Criteria	**Technological Criteria**
a) Objectives	**a) Online virtual lab platform**
b) Contents	**b) Text**
c) activities	**c) Image and graphics**
d) Evaluation	**d) Sound**
e) Feedback	**e) Video and animation**
	f) Navigation
	g) Simulation
	h) Interactivity
	i) Learning administration
	j) Publishing and technical support

8.1. Educational Criteria for DDOVLs

a) Objectives

- They should be specified clearly.
- They should be related to the contents.
- They should be formulated in the behavioral form.
- They should be measurable.
- They should be appropriate for the target learners.
- They should be shown at the beginning of each content.
- They should be described as not learning activity but learning outcomes.
- They should be arranged in a sequence according to expectations of the learning outcomes.

b) Contents

- They should be directly related to the educational objectives.
- They should be sufficient.
- They should be up to date.
- They should be objective.
- They should be easily understood, clearness and succinctness.
- They should be accurate in scientific and linguistic.
- They should be organized logically and sequentially.
- They should be designed according to self-learning strategy.
- They should be divided into small and gradual learning steps.
- They should be involved in summaries which describe the main ideas.
- They should be classified according to the types of the contents like practical or theoretical ones.
- They should be reviewed by subject-matter experts such as the teachers or the staffs.
- They should be rich with appropriate multimedia.
- They should be displayed in various forms, such as animations, simulations, figures, pictures, and videos.
- They should be supported linear and nonlinear presentation styles.
- They should be clearly specified by additional information linked to other websites.
- Their copyrights should be specified.

c) Activities

- They should be related to the OVL objectives.
- They should be suitable for the OVL contents.
- They should be defined clearly.
- They should be designed in a learner-centered way.
- They should send feedbacks to the learners.
- They should provide the learners with the time plan about online and offline learning such as starting time, duration, and deadline.
- They should be included in each contents' part.
- They should support cooperation among the learners in a synchronous and asynchronous way.

d) Evaluation

- It should be related to the educational objectives in the OVL contents.
- Its styles should be appropriate to the OVL objectives.
- It should be covered all the OVL contents.
- It should be clearly stated and understandable.
- It should have a variety in question types.
- Its questions should be ordered by difficulty level.
- Its questions should contain texts, image, graphics, sound, videos or animations related to the simulation.
- It should provide continuous formative evaluation during learning.
- It should provide summative evaluation after learning.

e) Feedback

- It should be provided immediately.
- It should be not general but specific.
- It should be suitable for the learners' level.
- It should be linked to the objective of the questions.
- It should be provided in several shapes such as texts, images, graphics, sound, video, and animation.
- It should guide the learners to the correct answer in the case of failure.
- It should support the learners with additional information to the correct answer.
- It should give the learners prioritized information about how their performances do or do not meet the objectives so that they can understand how to improve their future performance.
- It should be balanced in terms of the amount and timing to make it most effective.

8.2. Technological Criteria for DDOVLs

a) OVL Platform

- Its tools should be easy and clear to use and understand.
- It should be consistent and provide the learners with stable operation.
- Its design should be artistic and creative.
- It should provide search functions.
- Its hyperlinks should use the words that clearly identify where to lead.
- It should provide sufficient contrast between the text or images and the background.
- It should be divided into appropriate categories
- It should provide multiple channels of communication
- It should provide learning management tools.
- It should provide a display function for the contents.
- It should be easy to update the contents.

b) Text

- Text-based content should be limited.
- It should be clear and readable.
- Its font should be selected in appropriate styles and sizes.
- Its headlines should be structured by the font size hierarchically.
- Its titles should be simple and expressive.
- It should be formulated in short sentences and simple composition.
- It should be formulated in not passive but active forms and not contain interrogative forms.
- Its color should be suitable compared to the background.

c) Image and Graphics

- They must be original and relevant to the contents.
- They should be clear and not be crowded.
- Their color should be appropriate to reality.
- Their contrast and brightness should be balanced.
- Their digital effects should be related to real and not use visual tricks to hide from the truth.
- They should be highlighted to emphasize the meaning.
- They should show real dimensions.
- Their design should be suitable to ask the questions.
- Their quality should be facilitated perception.

d) Sound

- The number of it should be limited.
- It should be used to make clear the meaning.
- It should serve a clear purpose.
- It should be pure and not contain echo and noise.
- It should be a synchronize audio commentary with the display.
- It should be properly pronunciations.
- Its digital effects should be realistic and related to the contents.

- It should be high quality as much as possible.

e) Video and Animation

- They should serve a clear purpose.
- They should use at the necessary time.
- Their design should be suitable to ask the questions.
- They should synchronize with audio commentary if needed.
- They should be related to the achievement of the objective of the OVL contents.
- They should display with some control tools such as stop, repeat, sound, pause, and screen size.
- They should be high quality as much as possible.
- They should work to upgrade the level of critical thinking.
- Their speed should be designed according to specific tasks.
- They should increase learning desire.

f) Navigation

- It should be easy to move.
- Its labels should be easy to understand and express what they contain.
- Broken links should be avoided.
- Exit links should be provided at any time.
- Back links to the OVL platform should be provided from every page.
- Its links should use graphic buttons.
- Main navigation should be stable.
- Its links should be consistent and not crowded.
- Its structure should be organized logically by the appropriate labels such as categories, main links, and sub-links.
- Its links should be classified by category, color, providing links in a new page or using in the same page.
- It should avoid orphan pages.
- It should provide the learners with enough orientation by diagram, mind map, flow chart, instructional image and graphics.

g) Simulation

- It should be related to the contents' objectives.
- It should provide a virtual environment similar to the practical real objects.
- It should represent the theoretical idea easier to understand.
- Its images, graphics and theoretical idea should show the meaning as far as possible.
- It should be creative.
- It should provide interactive environment.
- It should harmonize with computer software used in the producing.

h) Interactivity

- Its multiple forms should be provided such as the teacher to the learners, the learner to the learners, and the learner to the contents.
- It should be provided in synchronous and asynchronous ways.
- It should provide the learners with full control.

i) Learning Administration

- It should provide a direct login to the OVLs.
- It should provide information about the OVLs' subject and courses.
- It should provide announcements such as next skills, encouragement for participation, time of contact, guides, results, and award, etc.
- It should provide information about new and emerging technologies such as Wikis, blogs, collaborative content development software, and video conferencing software, etc.
- It should offer functions to upload and download files.
- It should be balanced between cost and learning outcomes.
- It should provide tools for assessing performance in the OVLs.
- It should provide tracking function for learning.

j) Publishing and Technical Support

- The OVLs requirements about software and hardware should be specified.
- The server of the OVLs should have enough space in consideration of future expansion.
- The OVLs domain via the internet should be simple and suitable content types.
- The OVLs pages should be downloaded quickly.
- The OVLs should be controlled remotely from the host institution.
- The testing of the OVLs should be validated.
- The OVLs should be robust and sustainable to handle inadvertent damage by the students or malicious programs.
- The OVLs should be easy to maintain in terms of routine tasks like back-up.
- The OVLs should provide accessibility in anytime and anywhere.

- The OVLs should supply technical supports for the learners.
- The OVLs should have information about copyrights of educational institutions.

8.3. Features of DDOVLs Criteria

We have suggested the DDOVLs criteria to provide modern guidelines for the students in the department of educational technology and in the faculty of education for designing and developing process of the OVLs. Our criteria contain some new areas of elements related to the OVLs and virtual learning environments. First of all, the elements related to simulation represent the vital components of the OVLs with regard to experiments, skills, relationships, laws, and idea during the designing process. Secondly, the OVL platform criteria provide the framework about communication opportunities, and display of the OVL contents. In addition, the criteria related to the OVL learning administration are standard elements to provide the students with good management functions for learning inside the OVLs.

On the other hand, we add a new elements suitable to the OVLs to grow the main elements referred to educational criteria such as objectives, content, activities, evaluation, and feedback. These elements would make good guideline for designing the OVL contents. Furthermore, we pick up the criteria elements which belong to diverse types of multimedia such as texts, image, graphics, sound, video, and animation to become suitable to DDOVLs. We also suggest the criteria for publishing the OVLs to guide the students without technical errors.

9. CONCLUSION

In this paper, we proposed the instructional design model for designing and developing the OVLs in order for the students in the departments of educational technology and in the faculties of education to improve their skills with stable form and components in the near future schools and universities. We made the analyses of the previous studies about the OVLs in many fields and the previous instructional design models. Based on the results of the analyses, we proposed the instructional design model of DDOVLs focused on e-learning and virtual learning components suitable in modern educational systems. The proposed model contains six phases, pre-design, criteria, design, development, experiment and implementation, and evaluation which lead to produce the OVLs step by step.

In addition, we suggested the list of criteria for DDOVLs to provide the guidelines for the students. We had made the literature reviews related to virtual labs, e-learning, online technological resources, online courses and instructional websites besides miscellaneous aspects of educational technology. Depending on the reviews, we made a derivation of the DDOVLs criteria and organized them under two parts: educational criteria and technological criteria, which consist of 15 categories and 138 elements. These criteria would be used by the professors of educational technology in the criteria phase when teaching DDOVLs model to the students.

In the near future, we will apply the proposed model to the actual students in the both types of the students and valid the effectiveness in diverse fields in the actual educational institute. In addition, we will develop an OVL template to reach a pilot system for the OVLs and experiment it through practical use.

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