Virtual Laboratory for Engineering Education: Review of Virtual Laboratory for Students Learning

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***Abstract*—E-learning currently is a rapidly growing trend which attempts to provide an infrastructural configuration that integrates and encompass learning content, services and tools as a single solution which can generate and deliver educational contents and training effectively, efficiently and cost-effectively. In advanced technical education, laboratories are essential learning spaces. Providing laboratory facilities at universities with limited funds and technical know-how is difficult due to the high expenses of installation and upkeep. In order to tackle these obstacles, "virtual laboratories" are been established. Through remote access, virtual laboratories make it possible for users to conduct experiments similar to genuine systems. Consequently, resources of laboratories can be shared across a wide community of geographically dispersed customers while restricting operational expenses and initial set-up to one single institution. This article reviews the virtual laboratory for engineering education. Three distinct e-learning resource methods are discussed. The intrinsic objectives of animation are also explained. Lastly, the conclusion is provided along with recommendation for future studies.**

***Index Terms*—e-learning, students, learning, conventional laboratory, virtual laboratory**

I. Introduction

"Learning by doing" is not a novel notion. Allowing students to learn by doing in a classroom setting is a break from traditional techniques. In this regard, laboratories are essential components of education for gaining experience. Especially when considering the fact that engineering is an entirely applied subject, the significance of laboratory applications in training is readily apparent. Students engage in active learning in the engineering laboratory by seeing, observing, and doing. Such applications result in not only enhanced but also permanent learning. Numerous experts in scientific education have acknowledged that laboratory experiences boost students' enthusiasm and aptitude for science courses.

The proliferation of e-learning scenarios has been facilitated by the evolution of Internet technology and new methods of information exchange. In technological related fields like engineering, where laboratory activities and hands-on exercises are vital to students' learning, it is more difficult to develop online settings for practicals. Therefore, it is important to investigate the acceptance of technology by students and understand the process of adopting a learning environment which is online with web-based resources like interactive activities, virtual laboratories and educational videos including game-based learning approach. This study [1] asked 223 individuals to reply questionnaires in an online study and were examined by utilizing structural equation modelling. The research was based mainly on technological acceptance model (TAM) but also incorporated and evaluated aspects not explained by the TAM, such as perceived efficiency, fun, and contentment. The findings demonstrate that TAM extension is a valuable theoretical model used in understanding and explaining users' adoption of an online learning environment that includes physical practice and virtual laboratory. The findings also reveal that the original TAM variables and the students' adoption of this technology are positively influenced by the elements of efficiency, fun, and student satisfaction.

When approaching their first laboratory sessions, many university students lack confidence and experience nervousness. This is especially true for students studying at a distance. If these students are to derive the anticipated benefits from these laboratory sessions, it is crucial that they have access to the right prepared materials to mitigate this issue. Today, as a result of the rapid technological development in both hardware and software, a variety of solutions exist to overcome learning limitations, and as a result, educational activities have undergone several modifications. In addition, lecture management and the organisation of programs contents of a course rely heavily on multimedia tools that are based on many recent hardware and software innovations. They enable the introduction of novel and engaging arguments that would otherwise be difficult to teach as well as learn. In addition, the development of multimedia tools and the introduction of innovations on the multimedia sector result in the ongoing improvement of lecture's efficiency in terms of the organisation, the themes, the objectives and the quality.

In respect of the perspective of the students, numerous benefits can be realized. The students are engaged in a unique learning environment distinct from typical, well-defined laboratory and classroom settings. The use of virtual laboratory (VL) for example. It replaces the conventional laboratory with a virtual learning environment whereby the learning activities can possibly be conducted based solely on the needs of an individual. Specifically, the utilization of VL can be with intent to achieve the same aims as traditional education viz: face-to-face lectures; laboratory experiences and teaching staff consulting including improved quality, better outcomes, and far more expansion potential.

Remote learning as well as virtual laboratory are two most frequent online laboratories system kinds [2]. Considering end-users perspective, both seem extremely alike because they both provide online services accessible through website or alternatively by client application, but their backends are vastly different. As shown in Figure 1. In respect to remote laboratories, every piece of hardware like measuring equipment exists physically within an institution. Therefore, connecting the equipment to a network enables students to remotely control and evaluate the relevant portion of the experiment. In contrast, for virtual laboratory all the aforementioned components are totally recreated by software and are remotely accessible to users. Remote laboratories are utilized for both collaborative research and instruction, despite their distinct purposes. On the other hand, virtual laboratories are ideal with respect to educational purposes.

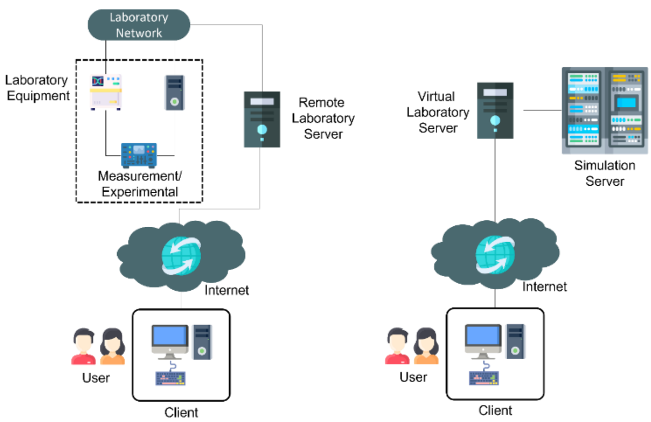

Fig. 1. The Primary Distinction Between Remote (Left) and Virtual (Right) Laboratories.

Regarding the benefits of virtual laboratories and remote learning, from the institution and the professor's standpoint, remote learning or virtual laboratory offers an opportunity to escape the physical limits of a conventional laboratory which makes the exercise accessible to a greater number of students since these laboratories all utilize info-communication technology, there is feasibility of following student's activities in order to get statistical data that can be used in creating helpful review on efficacy of a certain remote learning or virtual laboratory and to detect flaws with a given curriculum. The most tempting feature for students is the flexibility to conduct the experiment at their own pace and the lab's accessibility at any time and from any location.

As for the drawback of virtual laboratories and remote learning, its demerit relates to lack of physical touch with equipment and devices hence, remote laboratories do not tend to improve manual skill of the trainees like dexterity for instance, which are necessary to produce the same experimental outcome with working in reality with equipment. Utilizing high-fidelity 3D models of the equipment helps mitigate this effect to some degree. A further issue is the virtual environment can be deemed comparative with video games. Many students tend to lose their feelings as a result of viewing the virtual experiment as a video game and thus begin to exhibit seriousness towards the laboratory activities. In remote laboratories there is no possibilities of students causing harm by accident, as all regulated components have predefined limits that are monitored by the environment. In order to do the same experiment safely in a conventional laboratory, the same amount of discipline and prudence would be required.

As far as the positive aspects of using virtual laboratories are concerned, a huge percentage of laboratory experiments are unsafe or may be costly; consequently, thus, supervisors must be available in the laboratory in order to examine the student's theoretical knowledge before beginning the experiment. These two criteria preclude the student from concurrently performing the experiment and acquiring theoretical information through experiential learning. Students can also conduct experiments in a virtual laboratory in an environment that is safe, also, virtual laboratories can simulate critical conditions like distorted gravity or extremely excess ambient temperature that would be impossible or prohibitively quite expensive to achieve under traditional or remote laboratory therefore in the absence of actual equipment (hardware), the number of concurrent labs is limited only by system resources, and the virtual equipment does not get old or wear out, resulting in lower operational expenses. It is in addition less expensive to conduct a fresh experiment since no new equipment is required.

In consideration of the negative attributes of virtual laboratories the major disadvantage of a virtual laboratory over remote type is that: while remote laboratories are supported by real hardware thus reproduces the behavior of that hardware without the need to develop complex mathematical models which cannot account for all the details of an existing realistic physical system. However, the impact of this drawback is dependent on mainly the laboratory system's use case. Most times, the precision level which a mathematical model may reach is appropriate for educational and demonstrative purposes but it is essential to understand that the model as well as simulation will have to be comprehensive enough in order to encompass the main components of the exact experiment: it is essential to accurately mimic the phenomenon that is the focus of the laboratory experiment (for instance: ambient temperature affect the precision of a measurement equipment).

II. Three distinct e-learning resource methods

Three distinct e-learning resource approaches were discussed below [1]: virtual computer laboratories or simulations, instructional films, and game-based learning.

A. Virtual laboratories, simulators, and practical training

Laboratory work is an essential component of education in many fields of study, but notably in those that are eminently practical and technological, such as engineering [3]. In these fields, students must spend a significant amount of time addressing actual issues as well as simulating experience. Active learning activities that involve practical and physical hand exercises on equipment engage and encourage students more effectively than passive learning activities. Thus, it is necessary to provide learning tools that give students with opportunity to conduct research and get an understanding of how things function. Several authors have arrived at the same conclusion, with the majority proposing the creation of web-based virtual laboratories as the solution. Examples include the application of remote experimentation to regulate engineering education [4] also, virtual electrical machine laboratory that is web-based which can mimic laboratory courses in electrical engineering [5].

Based on recent report by Sheorey [6], virtual experiences that is well-designed for practicals could possibly replace actual experiments. In Similar understanding, Brinson [7] examined the learning outcomes of a conventional laboratory versus a remote, virtual laboratory. In all categories of learning outcomes, his findings indicate that virtual or remote laboratories produce equivalent or superior results than traditional laboratories. Similarly, Kolloffel et De Jong [8] discovered that students who used a virtual laboratory gained a deeper conceptual understanding and developed superior procedural abilities than those who used a traditional laboratory. According to De la Torre et al. [9], experimental settings can increase via virtual or remote laboratories accessibility, offering a framework for distance education that fits the hands-on learning needs of students. The use of virtual laboratories and/or simulations are effective tools in providing students in the engineering categories with the hands-on learning experience as well as practical tools [10], in also providing increased opportunities in autonomous learning plus practical problem-solving experience [11], reduction in teaching load, enhancing student motivation and facilitation of learning process [12]. In addition to enhancing the flexibility and accessibility of remote education, virtual laboratories can also improve its potential.

B. Instructional videos

The use of video is among the most popular and effective tools for virtual learning [13]. Numerous video lessons on any topic may be found on general platforms like Yahoo Video, YouTube, Vimeo, Screencast and Vidler, as well as on educational channels like Teacher TV, Teacher Tube, TED-Ed, the Khan Academy, School Tube and Open Courseware at MIT. Another instance in which video is employed as primary learning tool is MOOCs, in addition, many other universities in recent days employ a vast array of novel video strategies used for effective teaching-learning process, hybrid teaching environments, distance education as well as face-to-face teaching environments as strategy to supplement the curriculum or as an independent learning tool to reinforce sometimes complex concepts.

Numerous studies indicated that films are quite effective and valuable learning aid, resulting in large knowledge gains [14], student satisfaction, and enhanced learning outcomes [15],and the acquisition of reasonably improved practical abilities [16]. Many online educational videos have positive impact on student achievement when combined with classroom attendance [17]. Videos exhibit the potential to support the explanations of the teacher beyond the walls of classroom and provide students with geographical flexibility, allowing them to learn and assimilate at their own time, pace and then they can reflect on their understanding.

With respect to the usage of video podcasts for education purposes, at least two unique teaching methodologies have been identified: problem-based and receptive viewing. Receptive listening of podcasts presupposes that students would view learning content in a relatively passive manner, regardless of format (e.g., lectures, accompanying videos, PowerPoint slides). Problem-based video podcasts known also as working examples that provide audiovisual web-based explanations with procedural problems which students should answer in subjects like mathematics or courses that are science related [18]. The main advantages of receptive viewing with video podcasts usage include better learning and improved study behaviors, positive student attitudes toward this medium [14].

Problem-based video podcasts provide brief, web-based, audio-visual explanations on how to handle particular procedural problems in disciplines such as mathematics and science. Kay and Kletskin [14] examined 288 higher education students using a video podcasts for 59 problem-based that covers five key areas viz: operations with functions, linear functions, trigonometric functions, , solving equations, exponential and logarithmic functions as self-study tools to acquire pre-calculus skills over the course of three weeks. The results indicated that the majority of students utilised the video podcasts regularly, assessed them as useful or extremely useful, considered them as user-friendly and effective learning resources, and reported considerable pre-calculus knowledge increases.

C. Game-based education

Over time since the 1970s and 1980s, the popularity of video games has increased for the purpose of entertainment. Initially geared toward a male gender population video game business has made significant efforts in order to extend its market while appealing to a wider range of individuals, including women and families. The industry did not achieve this goal until the most recent years, as evidenced by Wii console system in addition to Facebook social games both of which have so many users worldwide. At the present time video games have become among highly profitable entertainment sector of the society and are also regarded as an emerging art form.

The major objective of game-based learning is to engage students in the learning process by increasing their interest as well as their motivation through elements like competition. Educational objectives are met through the employment of game elements like avatars, badges, collections, virtual commodities in learning processes, gifting, level progressions, quests, social graphs, and content unlocking [19].

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People, especially students, may learn a great deal through game-based instruction, which is why the popularity of game-based education continues to rise [20]. A number of authors have studied the influence of rewards on student motivation and engagement [21-24]. Significant potential exists for learning environments that is game-based in order to challenge and engage students using this active learning approach. In an instance, Dominguez et al. [25] found that among students that participated in a gamified scenario achieved higher grades on practical assignments. In a similar vein, Hwang, Wu, and Chen [26] tested a model experimental procedure through employing a web-based problem-solving exercise utilizing an online game and reported a significant improvement in students' attitudes towards learning, agreeing to the use of technology and become more interested in learning.

Gamification introduction into platforms with commercial success have been achieved, 3 particularly social ones, in order to develop close correlation between users and the platforms and to promote viral behaviour on them hence increasing popularity of the platform. Some academics hypothesize that this accomplishment might also be utilised in education as a strategy to boost students' engagement as well as motivate good learning practices. Online learning is one of the sectors where gamification can have a stronger impact due to its technical aspect. Its potential benefits may address well-known problems, such as the lack of student motivation resulting from restricted teacher and peer engagement. Additionally, both communication and monitoring architecture of e-learning platforms which makes provision for the required tools for including various gamification methods and measuring students' utilisation of them.

Among the typical game components seen in gamification literature are incentive systems and, in particular, the use of achievement badges [21, 27]. Abramovich et al. [28] defined educational badges as: firstly, typically issued to certify learning outside of formal institutions; secondly, visibility and number of views by others on the learner's profile; thirdly, granted for incidental action which is participation or skill and demonstration mastery of the acquired knowledge. Hence, badges indicate a recognition and reward for the success and engagement of the learners [29].

There are a lot of video game industries that are fast expanding and becoming a popular form of entertainment [29]. No longer are videogames merely software application that are operated on a personalized computer system by a single user utilizing just keyboard and a mouse, nor are they games loaded on specialized hardware such as game consoles. The evolution of computer hardware's processing and graphical capabilities contributed significantly to the development of the video game industry. The possibility of playing online using wireless networks and broadband; use of both tablets and smart hand phones as innovative delivery platform; the introduction of mixed reality technologies especially the augmented reality; improved user's interface in many game consoles including new patterns for interaction among players of the game such as natural gesture as instance.

All the listed advancement in technologies results in enhanced and novel gaming experiences such that users are in an almost realistic realm. Online games like Massively Multiplayer Online Games (abbreviated as MMOGs) such as World of Warcraft or online social games like Farmville or mobile games played on tablets and smartphones like 'Angry Birds' have an expanding number of users irrespective of ages, genres, ethnicities, and cultures. All of these players devote countless hours to playing these games on their cellphones, personal computers, and gaming consoles. Social games have grown especially popular among users of social networks. In recent years, the number of social gamers has increased substantially, and the majority of them utilize mobile devices to access these games. Numerous of these players are digital-game natives, having grown-ups playing video games [30].

Prensky [31] and Gee [32], among others, have emphasized the possibility of employing video games in education. Gee highlighted the influence of game play on cognitive development and identified 36 learning principles present in video games. In addition to the rise in video game's popularity, a movement formed to defend the expansion and application of aspects typically found in many video games also applicable to the real-world including sectors far from entertainment and video games. Games aimed at preventing world hunger or improving the quality of life for those with incurable conditions are examples (McGonigal, 2011). The Serious Games movement focuses on video games with educational goals as reported by Ulicsak & Wright, 2010. The use of games both casual and serious, to promote and support school learning is now recognized as Game-Based Learning.

Werbach and Hunter [33] present a framework containing a list of characteristics that can be used to operationalize gamification in order to provide guidance to practitioners wishing to gamify activities. This paradigm explains how these atomic, particular elements can be incorporated into a gamified process or activity. The identified items are presented Figure 2.

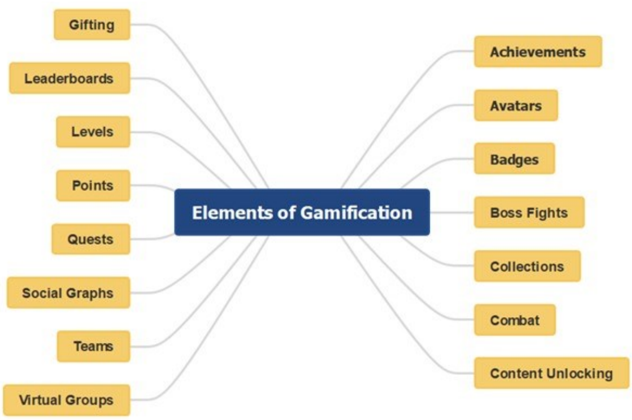

Fig. 2. Elements of Gamification.

III. FUNCTION OF MOTIVATION

As feedback, a dancing bear, a clown riding a unicycle, or exploding fireworks might stimulate students to strive for accurate answers. When utilizing animation as a form of feedback, designers must take caution. According to reports in [35] which state that by adding of "colorful graphic displays" would not increase motivation. As a matter of facts, aesthetically pleasing animation which occurs when an inaccurate response is made may tend to reinforce the mistaken response Therefore, it is crucial to emphasize positive motivation through animation.

A. *Presentation capability*

The most straightforward application of animation is as a component of a presentation strategy. In general, animation can provide a visual context and a concrete reference for ideas. Due to the connection between static and dynamic pictures, one could claim that animation can enhance the retention of information. Even if memorization is not the objective of a CBI, animation can aid in the presentation of information by outlining an idea, rule, or procedural step. Animation can also supplement the text by illustrating or expanding upon a topic, technique, or guideline.

When illustrating extremely abstract or dynamic processes, the using animation as a style of presentation approach is especially beneficial. For instance, animation may be very effective in assisting pupils to comprehend the circulation of blood within the body.

B. *Function of Clarification*

While there is close relationship between the clarification function and the presentation function, it utilises animation to provide conceptual clarity without adding novel information. In other words, the animation clarifies relationships visually. Relationships that are abstract and quite difficult in comprehension can be made easier to comprehend with the aid of animation. At a 'computer-based' economics course, for instance, the text may describe the correlation between factory worker's number and output of the assembly line. A plot graph that is animated may not contribute information, but it could explain the surrounding text and aid students in understanding the relationship between the two variables.

IV. Conclusion and recommendations

Virtual labs offer a number of potential advantages along with some disadvantages [3]. Virtual systems offer cost-effective means for institutions and schools to organize high-quality of lab work in especially with respect to STE subjects. It also has the ability to readily design a variety of 'virtual simulation' tests involving diverse components that is virtual apparatus. Moreover, multiple pupils are able to utilize the same virtual equipment simultaneously. Virtual labs also enable a change in configuration of the system in which makes it possible to edit parameters which are often inaccessible for real systems. For instance, by using robots a user can alter the linkages of the robot, change its motors to a stronger one, etc.

In terms of resistance to damages, for virtual environments, collisions are allowed with environment. For instance, the arm of the robot may collapse, but once a better and stronger one is replaced by the user then the robot will continue its task. Therefore, "injury" is permitted in the virtual world, allowing for the opportunity to learn from mistakes. Lastly, virtual labs are able to make the "unseen" visible: the majority of real lab gadgets are covered with protectors against dust and other external materials.; in most instances, the covers are permanently fixed and not removable or in some case difficult to remove. On the other hand, for virtual equipment, the covers are easily removable or alternatively transparent in order to display the internal structures; For robotic case as example, the arm can be opened to reveal the motors and gearboxes, allowing the user to observe and learn about the rotor, stator, gears, and other transmission components (like belts and spindles).

As far as the disadvantages of virtual labs, the first issue stems from demands placed on computer resources mainly. Dynamic modelling as well as 3D CAD modelling, for instance, may be quite difficult and time-consuming, particularly by integrating objects into a virtual environment that supports the ambiance concept. Other aspects are also inherent to a virtual system. Since the system does not exist, nothing truly negative can result. Students may feel like they are playing a video game due to this feature. It is not possible to have the same experience while viewing a machine simulation which is virtual like when standing in front of a 2-meter-tall moving machine. A similar problem occurs when a large robot manipulates a 100 kg load rapidly. Real-world experiences make learners immediately serious, more attentive and cautious. conclusively, it is an undeniable fact that the final phase of instruction involves genuine equipment; the only way to acquire these subtle abilities is frequently through 'actual hands-on' practice.

All in all, virtual laboratories are advantageous from an economic and organizational standpoint, but it is unclear whether they can meet the most important objective, which is assisting student learning. Therefore, it is critically important to evaluate study this question in the context of engineering subject. Future studies should contribute on assessing the methods which can be used in quantifying student learning both with regards to lectures as well as labs, thus entailing detailed assessment that results from an engineering course where virtual laboratory is used. It is also essential to examine the substantial theoretical and practical consequences of these web-based resources for instructional usage.

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