Artícle **Journal of Technological Development**
June, 2021 Vol.5 No.15 33-39

Virtual laboratories, an educational resource as a strategy for quality education

Los laboratorios virtuales, un recurso educativo como estrategia para una educación de calidad

HERNÁNDEZ-LÓPEZ Vianney†*, LOPEZ-VALDIVIESO, Leticia, MARTÍNEZ-IZQUIERDO, Carlos Mario and NOTARIO-PRIEGO, Ezequiel

Tecnológico Nacional de México/Instituto Tecnológico de Villahermosa

ID 1st Author: *Vianney, Hernández-López* / **ORC ID**: 0000-0001-9559-0418, **Researcher ID Thomson**: RID-17249, **CVU CONACYT ID**: 1083029

ID 1st Coauthor: *Leticia, López-Valdivieso* / **ORC ID**: 0000-0001-6288-3636, **Researcher ID Thomson**: G-5753-2018, **CVU CONACYT ID**: 67839

ID 2nd Coauthor: *Carlos Mario, Martínez-Izquierdo* / **ORC ID**: 0000-0001-9360-6714, **Researcher ID Thomson**: G-5753-2018, **CVU CONACYT ID**: 9623135

ID 3rd Coauthor: *Ezequiel, Notario-Priego* / **ORC ID**: 0000-0002-3791-1823, **Researcher ID Thomson**: RID-21285, **CVU CONACYT ID**: 407736

DOI: 10.35429/JTD.2021.15.5.33.39 Received March 26, 2021; Accepted June 28, 2021

Abstract

Virtual laboratories are considered the simulation of a real laboratory, where the behavior of a certain is studied using mathematical models, and although it does not interact physically with the processes or systems, experimentation with simulated models it is comparable to reality. The objective is to recognize the benefits that virtual laboratories offer the student, as a tool in problem solving, linking theory with practice, and developing teamwork, all within distance learning. Therefore, a compilation of different sources of information regarding virtual laboratories was made, where it is stated that the interviewees who make use of this tool for their learning obtained a favorable response by identifying that they develop skills that prepare them for their experimental participation in a future. Therefore, it is considered a strategy for quality teaching.

Virtual Laboratory, Educational resource, Quality teaching

Resumen

Los laboratorios virtuales se consideran la simulación de un laboratorio real, en donde se estudia el comportamiento de un determinado sistema haciendo uso de modelos matemáticos, y aunque no se interactúa de forma física con los procesos y/o sistemas, la experimentación con modelos simulados es comparable con la realidad. El objetivo del presente estudio es reconocer los beneficios que los laboratorios virtuales ofrecen al estudiante, como herramienta en la resolución de problemas, la vinculación de la teoría con la práctica y el desarrollo del trabajo en equipo, dentro de la enseñanza a distancia. Se realizó una recopilación de diferentes fuentes de información referente a los laboratorios virtuales en donde se reconoce que quienes hacen uso de dicha herramienta para su aprendizaje obtuvieron una respuesta favorable al identificar que desarrollan habilidadespara el desarrollo y participación experimental a futuro. Por lo tanto, se considera como estrategia fundamental para una enseñanza de calidad.

Laboratorio virtual, Recurso educativo, Enseñanza de calidad

Citation: HERNÁNDEZ-LÓPEZ Vianney, LOPEZ-VALDIVIESO, Leticia, MARTÍNEZ-IZQUIERDO, Carlos Mario and NOTARIO-PRIEGO, Ezequiel. Virtual laboratories, an educational resource as a strategy for quality education. Journal of Technological Development. 2021. 5-15: 33-39

* Correspondence to Author (email: leticia.lv@villahermosa.tecnm.mx)
† Researcher contributing first author

Introduction

Currently, the teaching-learning process faces new challenges and areas of opportunity that must be assumed from the guidelines and principles of operation that govern educational institutions. At the same time, the role assumed by the teacher is of utmost importance, since through adequate training in the use of technology, the necessary skills can be developed so that what at first seems complicated becomes an enriching experience for both the teacher and the student. It must be recognized that strategies must be implemented so that the student is able to make decisions, so it is necessary to generate resources to achieve not only significant learning, it must also be effective, ethical and with great responsibility.

Virtual laboratories, which by the potential it develops in students, should be considered a priority to enable institutions to achieve an experimental participation to understand the theoretical knowledge but especially to relate these basic theoretical principles with the practical part of the topics studied within the subjects. Performing all scheduled practices in a timely manner within an institution is sometimes complicated by the time pressure, because there may be restrictions on the use of resources or simply because it is not a safe activity for the student, so using virtual laboratories makes possible the simulation of something that perhaps in other circumstances could not be carried out. Therefore, through the compilation of information, the benefits of using laboratories to obtain quality teaching are presented.

Background

Virtual laboratories began to be developed in 1997 at the Academic Research Center of the State Distance University of Costa Rica. Judging from the information available on the Internet, they were among the first virtual laboratories for distance learning worldwide. Four years later, there was a similar commercial project, the Virtual Frog Dissection Kit 1.0. (http://www.cs.ubc.ca/nest/magic/projects/hands/home, February 2000) and three academics: Diffusion Processes Virtual Laboratory (Johns Hopkins University.

There were also two virtual reality level projects, requiring VR headsets, in the United States and Canada. (NASA Virtual Reality Virtual Object Manipulation, www.nasa.gov y Virtual Hand. Virtual laboratories were originally developed within space and military programs with huge budgets. (Monge Nájera, 1998, Dormido et al. 2000, Gil et al. 2003), over the years became the option for those who suffer from the opposite: small budgets. An extreme case is that of Cuba, where students must work in real laboratories that are obsolete and lack maintenance and Internet access, according to Alejandro (2004). In the case of Europe, which decided to implement virtual laboratories in a very different context, it is often not a matter of dealing with problems of inadequate laboratories or access difficulties, but of protecting students from hazards associated with chemicals or mechanical devices, while protecting equipment from damage due to carelessness during the learning process. (Salzmann y otros, 1999; Candelas et al. 2003, 2004a, b).

Although the use of virtual laboratories was not considered very frequent, however, there is research about it that has been done, in this research some will be cited to learn more about it.

Monge Nájera y Méndez Estrada (2007) evaluated the virtual laboratories used by the students of distance education sciences at the UNED of Costa Rica, during six years, they studied through surveys the level of satisfaction in each course to the users of 12 virtual laboratories and in the results they obtained they affirm that the ease of use of the virtual laboratories is "good or excellent", it is pleasant to execute them and the illustrations and other graphic aspects are good.

On the other hand, Infante Jiménez (2014) points out those virtual laboratories are a valuable digital tool that effectively complements laboratory practice, with the advantages of being always available and accessible. The use of the virtual laboratory tends to rationalize the use of resources, decrease the negative impact on the environment and minimize the risks associated with occupational health.

ISSN 2531-2960

Likewise, Morales Castro et al. (2015) share that virtual laboratories are a support and complementary tool for the teacher, allowing him to innovate in traditional teaching, it is important to note that they do not replace real laboratories. Among its advantages, it is possible to repeat the practice at the request of the students in a reasonable time without affecting any other programming of a laboratory, contributing to the formation of professionals with quality and skills according to their profile of graduation, in addition, students use current technological tools and the incorrect use of physical equipment is reduced.

Vergara Rodríguez (2019) analyzed the opinion of students in relation to technological applications, and the positive experiences that are being lived in practical teaching by using virtual laboratories (LV) that reflect a number of clear advantages over traditional practical classes in real laboratories, the imposition of the LV in the educational sector is an unstoppable fact.

It is of vital importance that nowadays the continuity of the classes in a non face-to-face way does not affect especially the students who have to take subjects that require a fundamental experimental part. It is necessary to be aware that today's young people require a broad knowledge by linking theory with practice. Therefore, it is recognized that the lack of preparation of many university graduates to solve the problems they face in their first areas of professional practice, which translates into difficulty in entering the field (Morandi 1997). Based on the above, it is possible to highlight "know-how", that is, practical knowledge (Bourdieu 1991).

This problem could be considered as one of the main causes for the lack of interest in learning and dropping out of school. As stated by (Crissman and Upcraft 2005), the highest percentage of dropouts is concentrated in the first years, which is affirmed by the following: Teachers' commitment is essential and relevant when it comes to diminishing, and in the best of cases avoiding, such an outcome (Siegel 2005).

Virtual laboratories and their similarity to reality

In the field of computer science, the term virtual means "not real". In general, it distinguishes something that is purely conceptual from something that is physically real.

Such a distinction can be used in a wide variety of situations. This defines a virtual laboratory as a computer simulation of a wide variety of situations in an interactive environment; that is, the behavior of a given system to be studied can be simulated using mathematical models, and although there is no interaction with real processes or systems, experimentation with simulated models is comparable to reality, provided that such models are realistic and represent important details of the system to be analyzed, and that the graphs representing the temporal evolution of the system are complemented with animations that make it possible to see and better understand the behavior of the process.

Generally, a digital laboratory manual is available, in the same way as in a physical laboratory, but a guide with instructions for carrying out the experimentation is also required. Communication between the teaching staff and the learner is usually through the electronic manual, leaving the option for those who have doubts to use the telephone, e-mail or a similar medium (Sowizral et al., 2000; Sebastián et al., 2003).

The virtual laboratories are made up of a mathematical model, algorithms to follow the instructions and be able to follow the model and the conversion of the language through a computer to facilitate the input of information and obtain results.

Importance of Virtual Labs as a strategy in practical teaching

They represent an alternative to be able to perform the practices and repeat them as many times as necessary, and thus reaffirm the knowledge, even without being physically in a traditional laboratory.

Virtual laboratories are computer tools provided by Information and Communication Technologies that simulate a chemical testing laboratory from a virtual environment (Cabero 2007). The virtual modality for teaching experimentation makes it possible for students to study at distant distances and put their knowledge into practice. Compared to a real laboratory, costs are greatly reduced, especially when the appropriate furniture is not available, which generates very high costs for institutions that cannot assume such costs.

ISSN 2531-2960

Advantages of using virtual laboratorios

According to Méndez, Monje and Rivas, (2001) the use of virtual laboratories allows to obtain the following benefits:

- Expand course coverage.
- Decrease the costs of transportation, food and lodging for students.
- Simulate situations that in reality would have little chance of being carried out.
- Repeat events or phenomena as many times as required.
- Relate phenomena to their consequences.
- Develop skills in the use of the computer.

The creation of virtual laboratories has multiple advantages over real laboratories. Since this type of laboratories are based on mathematical models that run on computers, their configuration and operation is simpler. In addition, they have a higher degree of safety since there is no risk of accidents in the environment as there is no physical equipment or devices.

Another no less significant advantage derives from economy, since less is invested in equipment, materials and reagents. From the environmental point of view, by not using reagents that are sometimes toxic, the preservation of the environment is favored, since no polluting residues are discharged into the atmosphere or into the drains; in this sense, the health of the students is also ensured since they are not in contact with these materials.

Students learn through trial and error, without fear of suffering or causing an accident, without being ashamed to perform the same practice several times, since they can repeat them without limit; without fear of damaging any tool or equipment (Rosado and Herreros, 2009).

Sousa Ferreira et al. (2021) consider that virtual reality is especially useful when working with events and consequences very close to the daily professional development of a network technician. A practical case is situations in which the student needs to associate hard skills (technical knowledge of programming and cybersecurity to solve problems in computational environments) with soft skills (empathy, emotional intelligence and citizenship education).

Virtual reality is a tool that can help transform educational models, bringing improvements in the teaching-learning process. However, it may not be the most appropriate tool in all cases. Therefore, a thorough analysis of the teacher and all the sectors involved in education is necessary to approach the best model to guarantee learning.

Analysis of results of previous studies

Among the contributions of some authors, Morales Castro's (2015) was considered, where he states that out of 30 respondents, 25 consider that they develop more competencies by practicing virtually, since they can do so whenever they wish without being subject to schedules and the existence of the necessary physical equipment. Therefore, in percentage this is equivalent to an 83% positive response regarding the use of virtual laboratories.

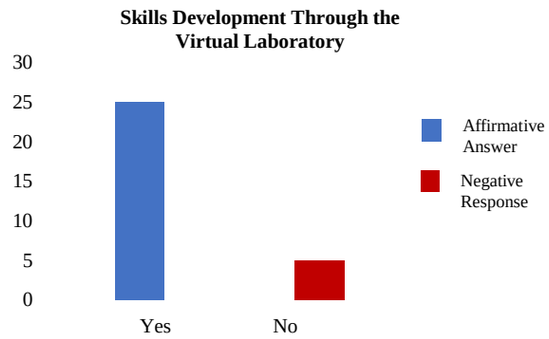

Figure 1 Respondents' opinions
Source: Morales Castro (2015)

The following table shows the competencies that will be developed through the use of virtual laboratories:

Competencies
– Capacity for analysis and synthesis.
– Ability to organize and plan.
– Communication skills.
– Skills in handling technology.
– Research skills.
– Problem solving.
– Decision making.
– Critical thinking.
– Teamwork.
– Responsibility.
– Collaborative learning.
– Exchange of ideas.

Table 1 Competencies to be developed
Source: Morales Castro (2015)

ISSN 2531-2960

Methodology

The main objective of this research is to recognize that virtual laboratories are a tool that facilitates teaching and learning strategies, so the advantages of using this tool were analyzed through a measurement instrument consisting of 10 questions that reflected the importance of the use of laboratories in quality teaching, by the respondents.

Development of cognitive skills	Frequency of answers			
	Never	Occasionally	Regularly	Always
Clarity and precision	3	7	13	7
Problem solving	4	11	10	5
Technological skills	3	7	15	5
Decision making	4	12	12	2
Confidence in the practice	6	10	10	4
Ideas approach	4	8	15	3
Useful tool as a teaching strategy	Academic Education		Quality Education	
	Yes		No	
	24		6	
	19		11	

Table 2 Aspects evaluated in the measurement instrument
Source: Own contribution December 2021

Table 2 shows the items that were evaluated and the frequencies of the responses that were compiled from the results. A total of 30 instruments were applied to high school students.

Analysis of results

Based on the instruments applied to the 30 students, the results shown in Table 3 were obtained.

Development of cognitive skills	Relative frequency:			
	Never	Occasionally	Regularly	Always
Clarity and precision	0.10	0.23	0.43	0.23
Problem solving	0.13	0.37	0.33	0.17
Technological skills	0.10	0.23	0.50	0.17
Decision making	0.13	0.40	0.40	0.07
Confidence in the practice	0.20	0.33	0.33	0.13
Ideas approach	0.13	0.27	0.50	0.10
Average	0.13	0.31	0.42	0.14
Value in percent	13%	31%	42%	14%
Useful tool as a teaching strategy	Academic Education		Quality Education	
	Yes		No	
	0.80		0.20	
	0.63		0.37	
Average	0.72		0.28	
Value in percent	72%		28%	

Table 3 Relative and average frequency values of evaluated aspects
Source: Own contribution December 2021

In relation to the development of the cognitive skills that are brought down in the use of the virtual laboratory, 42% of the respondents (as shown in Figure 2) develop the competencies mentioned in Table 4 below.

Development of cognitive skills in the use of the virtual laboratory

Competencies to be developed
– Clarity and precision.
– Ease in problem solving.
– Development of technological skills
– Practice in decision making.
– Confidence in internships.
– Ideas approach.

Table 4 Competencies to be developed in the use of virtual laboratories
Source: Own contribution December 2021

The following graph 2 shows the average frequency in which the cognitive skills are developed with the use of the virtual laboratory.

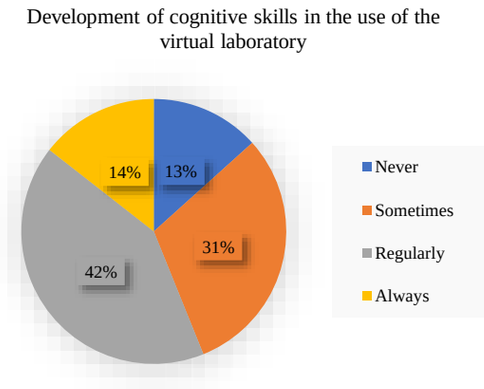

Figure 2 Relative frequency of cognitive skills development in the use of the virtual laboratory
Source: own contribution December 2021

Graphical representation of the impact of the use of the virtual laboratory as a teaching strategy (Graph 3), based on the results shown in Table 2 and Table 3, of the 30 respondents, 24, equivalent to 80%, consider that the use of the virtual laboratory is important for their academic training. Likewise, 11 (63%) agree that the use of the virtual laboratory is a strategy that favors quality teaching.

ISSN 2531-2960

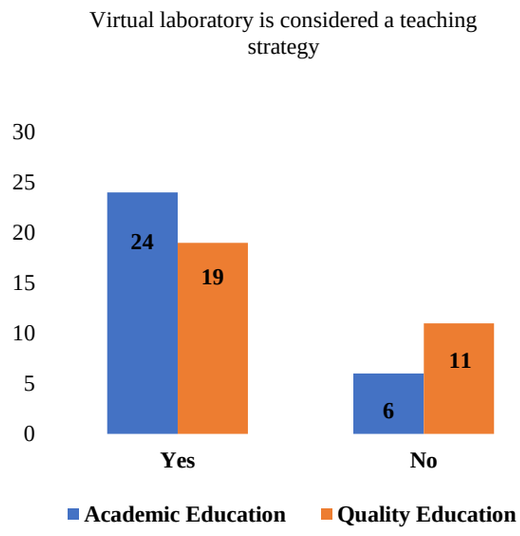

Figure 3 Relative frequency of the importance of the use of the virtual laboratory as a teaching strategy
Source: Own Contribution December 2021

Conclusions

The use of a virtual laboratory facilitates student learning, helps in the repetition of knowledge, you can perform the practice as many times as necessary, offers many advantages ranging from analyzing the scenario of a real situation, to develop skills of analysis and evaluation of results, making the approach of solutions. On the other hand, it encourages the student to feel interest, when part of the knowledge can be felt through the virtual representation, thus giving better results in their performance as students, achieving the goals of teaching, looking for students to achieve critical thinking, to be creative and develop complex cognitive skills, to obtain a quality education. Therefore, it confirms what Morales Castro (2015) said that when using the virtual laboratory, constructivism is applied since the student "learns by doing" by integrating theoretical knowledge with practice, in addition to linking learning with real situations that will be presented in the work environment.

Therefore, the following competitive advantages are developed in the use of the virtual laboratory as:

– Clarity and precision. Performing an internship as many times as necessary to apply theoretical knowledge allows for the development of ideas, which prepares the student to develop his or her decision-making skills.

– Problem solving. Through an initial approach the student is able to assume a conclusion from a result obtained.

– Development of technological skills. This prepares the student and the teacher to interact in a virtual environment, and improves learning, especially in computer science.

References

Alejandro, A., C. A. (2004). General physics laboratory practices on the Internet. [Electronic version]. Electronic Journal of Science Education, 2(3), 1-5.

Bourdieu, P (1991). El sentido práctico. Buenos Aires. Ed. Taurus humanities.

Cabero, J. (2007). Las TICs en la enseñanza de la química: Aportaciones desde la Tecnología Educativa, in Bódalo, A. et al. (eds.): Química: vida y progreso, Asociación de químicos de Murcia, Murcia (ISBN 978-84-690-781).

Candelas, F. A., Gil, P., Ortiz, F. G., Pomares, J. A. Puente, S. T. y Torres, F. A. (2003). Laboratorio virtual para la enseñanza de la robótica. International Journal of Engineering Education, Special Issue "Remote Access /Distance Learning Laboratories", 19, 363-370.

Candelas, F. A., Gil, P., Ortiz, F., Pomares, J. A., Puente, S. and Torres, F. A. (2004). The virtual laboratory as a tool in the teaching-learning process. Investigar Colaborativamente en Docencia Universitaria. In: Actas de las II Jornadas de Redes de Investigación en Docencia de la Universidad de Alicante, (unpaginated). Alicante: Editorial Club Universitario. http://aer.ual.es/publica_es/Posters/PosterROBOTMOVIL.pdf

Candelas, F. A., Gil, P., Ortiz, F., Pomares, J., Puente, S. T. and Torres, F. A. (2003). Visual: A practical tool for teaching Computer Vision. 1st Conference on Machine Vision Education and Practice, (pp. 115-121). Mallorca: (s.e).

Candelas, F. A., Gil, P., Ortiz, F., Pomares, J., Puente, S. and Torres, F. A. (2003). Virtual Laboratories for hands-on learning of engineering subjects. In: I Jornadas de Redes de Investigación en Docencia Universitaria, (unpaginated). Spain: Editorial Club Universitario.

Candelas, F. A., Navarrete, J. A., Pomares, J. A., Puente, S. T., Segarra, V., Torres, F. A. (2004, abril). A flexible JAVA Class Library for Simulating and Teleoperating Robots, 11 th IFAC Symposium on Information Control Problems in Manufacturing (INCOM04), Salvador de Bahía, Brasil.

Crissman, J., y Upcraft, M. L. (2005). Las claves de la persistencia de los estudiantes de primer año. En Upcraft Lee M., John N. Gardner, Betsy O. Barefoot & Associates.

Deering, M., Rushforth, K. y Sowizral, H. (2000). The Java 3D API Specification. (2ª ed.). New York: Addison-Wesley.

Dormido, S., Sánchez, J. and Morilla, F. (2000). Virtual and remote laboratories for the remote practice of Automatics. XXI Jornadas de Automática, Plenary lecture, (unpaginated). Seville, Spain: s.e.

García, D., Sánchez F. M. y Sebastián, J. M. (2003). Educación a distancia basada en la adquisición y procesamiento de imágenes a través de Internet, IEEE Transaction on Education, 46, 142- 148.

Gillet, D., Mondada, F., Salzmann, Ch., y Saucy, P. (1999). Sharing of Unique or Expensive Equipment for Research and Education, Informatik / Informatique, Magazine of the Swiss Informatics Societies, 4, 32-33.

Infante-Jimenez, C. (2014) Pedagogical proposal for the use of virtual laboratories as a complementary activity in theoretical-practical subjects. Revista Mexicana de Investigación Educativa, (19)62, July-September, 2014, pp. 917-937.

Méndez, V. H., Monge-Nájera, J. y Rivas-Rossi, M. (2001). Internet, multimedia y laboratorios virtuales en un entorno "tercermundista". Open Learning, 3(16), 279-290.

Monge-Nájera, J. (1998). La estrategia CIAC 2000. San José, Costa Rica: EUNED.

Monge-Nájera, J. and Méndez-Estrada, V. H. (2007) Advantages and disadvantages of using virtual laboratories in distance education: the students' opinion in a six-year project Education. Education Journal ISSN: 0379-7082 31(1).

Morales-Castro, C., Zozaya-Salas, R. G., Rojo-López A. and Torres-Balcazar, A. (2015). Virtual laboratories as an alternative for the development of professional competencies. Iberoamerican Journal of Academic Production and Educational Management ISSN 2007 - 8412, 201.

Morandi, G. (1997). The theoretical-practical relationship in the training of professionals: problems and perspectives. Paper presented at the 2nd Conference on Update in Dentistry. Faculty of Dentistry, UNLP.

Rosado, L. and Herreros, J. (2009). "Nuevas aportaciones didácticas de los laboratorios virtuales y remotos en la enseñanza de la Física", Recent Research Developments in Learning Technologies, International Conference on Multimedia and ict in Education, 22-24 April, Lisbon. Available at: www.formatex.org/micte2009/.

Siegel, B. (2005). Invitando al éxito a los estudiantes de primer año: la perspectiva de un presidente. En Upcraft Lee M., John N. Gardner, Betsy O. Barefoot & Associates.

Sousa-Ferreira, R., Campanari-Xavier, R.A., & Rodrígues-Ancioto, A.S. (2021). Virtual reality as a tool for basic and professional education. General Scientific Journal José María Córdova, 19(33), 223-241.

Vergara-Rodriguez, D. (2019). Imposition of virtual laboratories in 21st century education. Journal of Information and Communication Technology in Education 13(2).