Hindawi
Education Research International
Volume 2022, Article ID 8605202, 12 pages
https://doi.org/10.1155/2022/8605202

Research Article

The Reality of Using Virtual Labs in Teaching Advanced Biology Curricula in Developing Higher-Order Thinking Skills (HOTS) among Female Teachers at Secondary Level in Al-Kharj

Asma Abdulrahman Nami Alshaikh

Curriculum and Teaching Science Methods, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia

Correspondence should be addressed to Asma Abdulrahman Nami Alshaikh; a.alshaikh@psau.edu.sa

Received 18 May 2022; Accepted 21 June 2022; Published 5 July 2022

Academic Editor: Ehsan Rezvani

Over the last few years, the use of the web and virtual technologies in school education has become widespread. This study aimed at identifying the reality of using virtual laboratories (VLs) in teaching advanced biology curricula in developing higher-order thinking skills (HOTS) among female students at the secondary level in Al-Kharj district, Saudi Arabia. The study adopted descriptive methodology. Fifty-four biology female teachers at the secondary level in Al-Kharj completed a questionnaire consisting of four dimensions: the awareness of the virtual laboratories' importance in developing higher-order thinking skills, the use of virtual laboratories in developing higher-order thinking skills, obstacles to using virtual laboratories in teaching advanced biology curricula, and the requirements for using virtual laboratories in teaching advanced biology curricula to develop higher-order thinking skills. The results showed the awareness of the VLs' importance in developing higher-order thinking skills achieved with a large degree, using VLs with a middle degree, the impediments of using VLs in developing higher-order thinking skills with a large degree, and the requirements for using VLs in teaching biology for developing higher-order thinking skills with a very large degree. The results also showed statistically significant differences between the responses of the female teachers according to the number of training workshops in VLs. There were no statistically significant differences with regard to the academic degree and the years of experience. The study recommended a reconsideration of technological infrastructure in schools where VLs are used in teaching and learning.

1. Introduction

The current era is described as the one with a technological revolution that is witnessing rapid and successive developments in the fields of technology and digital communications, which led to the spread of the use of computers and the internet in various areas of life. It has made it necessary to introduce technologies in education and benefit from them for the development of the educational process suitable for the 21st-century digital generation.

Many educators stress the importance of employing available technical tools in the field of education as there is a strong relationship between science and technology. If science is interested in the search for knowledge to understand, explain, and interpret the phenomena surrounding the learner, technology is interested in searching for how to apply knowledge to serve the individual and society [1]. Keeping in view the dearth of studies in this field in the Saudi context, this study is conceived to be conducted in the Al-Kharj district of Saudi Arabia.

Al-Shehri [2] affirms that the changes in the current era towards the use of educational technologies have led to the development of the educational process and achieved the objectives of education more effectively, thus improving the quality of education (p. 176). Virtual reality applications represent an artificial or fictional learning environment simulating a reality where the learner lives in an imaginary environment, which interacts and deals with their senses with the help of the computer and other assistive devices. [3].

Howlett and Uskov [4] believe that a virtual lab is a software package that allows performing research and experiments without the need for real arrangements (p. 221). The main task of VLs is to assist the stimulation and presentation of experiments and science learning based on an experiment.

Woodfield et al. [5] indicate that VL is an open environment in which a real science laboratory is simulated and the theoretical aspect is linked to the practical side, and thinking skills are taught through it and students have complete freedom to make decisions with no negative effects (p. 1728).

VLs are distinguished by their high technical specifications in conducting, displaying, and repeating laboratory experiments and facilitating communication between the teacher and the learner [6]. It also gives the learner a great ability to visualize and understand concepts. Yaron et al. [7] assert that there are great advantages of using VL in teaching chemistry and it has a great effect on students' participation and their concepts (p. 181). Virtual experiments go beyond the limits of space and time as they provide safety and security [8]. Some research studies confirm that virtual lab submerges learners to deal with things naturally, so that they develop positive attitudes towards learning science [9, 10].

VLs also contribute to overcoming the obstacles that prevent the practice of realistic experiences and are considered an alternative to traditional laboratories as they provide students with virtual experiences very close to direct experience [11]. Al-Shehri [12] adds that with the help of virtual lab, it has become possible for the learner to perform experiments that he cannot otherwise perform in a traditional setting due to various factors including risk, lack of devices or tools, high cost, lack of time, and lack of material (p. 3).

Many research studies have proved the effectiveness of VLs in providing learners with practical knowledge and skills in different science subjects. Hazaa and Qutb [13], for instance, showed the effectiveness of VLs in developing the achievement of high school students of physics. Similarly, the results of the study of Tatli and Ayas [14] also showed positive effects of using the VL on the students' results in chemistry and their ability to follow experiment procedures and write the experiment report accurately and quickly.

Hegazy [15] showed the effectiveness of using VLs in developing practical skills in chemistry among first-grade secondary students. Al-Shehri [12] explained the effectiveness of using VL in providing third-grade secondary students with the skills of conducting practical experiments in biology. Furthermore, the results of Al-Radi [16] showed a positive effect of using VL in the achievement of chemistry among third-grade secondary school students. On the other hand, the results of many studies indicated the importance of using VLs in teaching science curricula in developing the critical thinking skills of the learners. Al Musawi et al. [10] also indicated the effectiveness of using the VL in developing scientific, logical, and visual thinking skills, and talked about trends towards using VLs in teaching science. Ahmed [9] concluded that there is a positive effect of using VL in teaching science as it develops higher thinking skills and motivation among third-year middle school students.

Despite the great benefit of using VL in teaching science curricula, there are some obstacles that limit their use. As Zaiton [17] mentioned that VLs need computers and equipment with special specifications to represent complex phenomena and need a specialized team of programmers, teachers, curriculum experts, subject matter experts, and psychology experts in their design and production (pp. 165-166). Nikoonezhad and Esfahani [18] mentioned some hurdles in using VLs, including the lack of infrastructure and the provision of software, weak interaction between teacher and students, failure to design professional and interesting programs, and the lack of experts specialized in producing VL programs for local curricula.

To keep pace with the global development in the field of education, particularly, biology, it has become necessary to pay attention to the learning biology environment and to provide all appropriate learning opportunities and bring about fundamental transformations in teaching and learning methods so that learning biology transforms from closed learning environment represented in traditional teaching methods, in which the teacher is the only source of knowledge and information, to a flexible and open learning environment that focuses on providing and employing technological innovations and providing learners with different thinking skills through focus on the learners' activity, positivity, and participation in their learning decisions. Hence, there was a need to reveal the reality of using VL in teaching advanced biology curricula in developing higher thinking skills among secondary school students in Al-Kharj.

1.1. The Statement of the Problem. The branches of science subjects need to be taught in the school laboratory as it is particularly crucial to explain and interpret some difficult and abstract concepts that are otherwise difficult to understand in ordinary ways. Thus, the school laboratory has a great importance in translating theories and laws into practice. The development of thinking skills requires modification in activities, methods, and use of technology allowing students the freedom to research, investigate, and discover in line with their abilities and previous experiences [19]. Despite the crucial importance of laboratories in teaching science subjects, some obstacles prevent their optimal use. The American National Research Council report confirmed that science laboratories lack quality and necessary equipment, which leads to the inability of the learners to benefit from them in a way that develops their various skills [20]. Therefore, modern methods, tools, and procedures have emerged as solutions to the obstacles faced by the school laboratory, and among those technical tools, the VLs are considered the most prominent modern trend in teaching science curricula [21]. Moreover, despite the importance of VLs in teaching advanced biology curricula, there are several deficiencies. During field visits and interviews, researchers noticed some problems pertaining to employing biology teachers in VLs for teaching the advanced biology curricula and implementing experiments. Other problems include a large number of female students in classes and a lack of female teachers' awareness of how to use VLs in teaching advanced biology curricula in developing higher-order critical thinking skills, metacognition, and problem-solving. Furthermore, many high schools in Al-Kharj do not have laboratories equipped enough to use VLs.

In light of the remarkable interest in the Kingdom of Saudi Arabia in recent years to develop and improve its curricula to keep pace with developed countries and achieve the 2030 vision, the development of higher thinking skills is considered one of the most important goals of science curricula in all its branches, including biology curricula. There is a need to complete the learning resource rooms project, which started in some schools of the Kingdom, as well as supplying laboratories in secondary schools with tools, devices, techniques, and materials that facilitate the implementation of various activities, practical experiments, and computer presentations. The study also recommended including VLs in the advanced biology curricula to support investigation skills and provide students with skills and experiences that they cannot do in the typical laboratories. Reda [22] recommended the necessity of training science teachers in general on using VLs.

In light of the aforementioned discussion, the study problem can be identified in the following main question: "What is the reality of using VLs in teaching the advanced biology curricula in developing higher thinking skills among high school students in Al-Kharj?". The following subquestions emerge from it:

(1) What is the awareness level of biology teachers regarding the importance of using VLs in developing higher thinking skills among secondary school students in Al-Kharj?
(2) What is the level of biology teachers regarding using VLs in developing higher thinking skills among high school students in Al-Kharj?
(3) What are the obstacles in employing biology teachers in VLs for the development of higher thinking skills among high school students in Al-Kharj?
(4) What are the requirements of employing biology teachers in VLs for the development of higher thinking skills among high school students in Al-Kharj?

1.2. Research Objectives. The objectives of the study are to

(1) Identify the biology teachers' awareness level of the importance of using VLs in developing higher thinking skills in high school students in Al-Kharj.
(2) Identify the biology teachers' level of expertise in using the VLs in developing higher thinking skills in high school students in Al-Kharj.
(3) Identify the obstacles in engaging the biology teachers in the VLs in developing higher thinking skills in high school students in Al-Kharj.
(4) Identify the requirements of engaging the biology teachers in the VLs in developing higher thinking skills in high school students in Al-Kharj.

1.3. Significance of the Study.

(1) The study is significant in terms of responding to the recent trends in using VLs and their software to achieve various learning outcomes in the advanced biology curricula.
(2) It is significant in terms of revealing the obstacles that hinder the activation of VLs in the teaching of the advanced biology curricula to achieve the development of higher thinking skills in high school students making them ready for making decisions.
(3) The results of the study reveal the requirements for VLs and benefits from them in developing higher-order thinking skills drawing the attention of the officials of the Ministry of Education to provide those requirements.
(4) The recommendations of the study are significant in terms of providing the proposed solutions to activate the VLs to develop higher thinking skills in the biology curricula in high school students.

1.4. Limitations of the Study.

(1) Objective limits: The study was limited to VLs in teaching the advanced biology curricula.
(2) Spatial boundaries: The study was limited to secondary schools in Al-Kharj district.
(3) Human limitations: The study was limited to the advanced biology curricula teachers in Al-Kharj district.
(4) Limitation of time: The study tool was applied in the second semester of 1442 AH/2021 AD.

1.5. Key Concepts of the Study

1.5.1. Virtual Laboratories. VLs are interactive virtual electronic laboratories that contain computers linked to the Internet and enhanced with computer educational programs to teach advanced biology curricula at the secondary level to provide students with higher thinking skills. VLs provide "[a]n interactive environment that aims to conduct and implement experiments that simulate the real experience, as it is a field for laboratory experimentation, and the VL includes programs that are subject to the simulated field." [6].

1.5.2. Advanced Biology Curricula. It is one of the educational series prepared by McGraw Hill Education providing educational curricula in cooperation with the A'beikan Research and Development Company due to which it was translated and adapted to become suitable for the local environment. These curricula include all the experiments from prescribed books and student activities guide and their educational activities related to the goals of the curriculum, and teachers' evidence and what they use in terms of teaching methods, techniques, and methods of evaluating students' learning [23]. Defining it procedurally, it is the biology curricula (2021 edition) applied by the Ministry of Education in the Kingdom of Saudi Arabia, which is compatible with the global McGraw Hill series. It was translated and adapted to the Saudi educational environment in 2009.

2. Research Methodology and Procedure

2.1. Research Methodology. The study followed descriptive and analytical methods.

2.1.1. Research Population and Sample. The population of the study consisted of all science teachers in government schools at the secondary stage during the second semester of the academic year 1442 AH/2021 AD. The study sample was limited to 54 biology teachers at the secondary level in Al-Kharj. Table 1 shows the distribution of the teachers according to the following variables: academic qualification, years of experience, and number of workshops in VLs [24].

2.1.2. Research Tool. To achieve the study aims, a questionnaire was prepared consisting of 41 items distributed on four main dimensions, namely, biology teachers' awareness of the importance of VLs in developing higher thinking skills, the use of VLs in the development of higher thinking skills, the obstacles in using VLs in the teaching of advanced biology curricula, and the requirements for using VLs in teaching advanced biology curricula to develop higher-order thinking skills. The questionnaire was prepared initially in the light of what was mentioned in previous studies, which dealt with the use of VLs in science teaching at the secondary level and other educational levels [24]. The reliability of the questionnaire was checked through the Cronbach alpha formula, and it was 0.89.

2.1.3. The Validity of the Referees. To verify the validity and relevance of the study to achieve the study aims, it was presented to a group of referees from the faculty members of some Saudi universities to seek their views regarding the accuracy of the scientific and linguistic formulation of the questionnaire items, and the extent to which each item belongs to the domain in which it is mentioned, and making any observations related to adding more appropriate items and deleting the inappropriate items, and in the light of the referees' opinions, some amendments were made to the initial image of the questionnaire [24].

2.1.4. The Validity of the Internal Consistency of the Questionnaire. To verify the validity of the internal consistency of the questionnaire, it was applied to an exploratory sample consisting of 20 female teachers who were not part of the study sample. The correlation coefficient was computed between the score of each item in the questionnaire and the total score of the domain to which it belongs, and the results are shown in Table 2.

It is evident from the results that the score of each item in the questionnaire is related to a significant correlation coefficient at a significance level of 0.01 or 0.05 with the total score of the domain to which it belongs. The correlation coefficients were calculated between the score of each domain separately and the total score of the questionnaire, and the results are shown in Table 3.

It is evident from these results that the score of each domain correlates with a significant correlation coefficient at a significant level of 0.01 with the total score of the resolution. These results confirm that the questionnaire has a high degree of internal consistency validity [24].

2.1.5. Stability of the Questionnaire. To verify the stability of the questionnaire, the alpha Cronbach reliability coefficient was calculated for each item and the questionnaire as a whole. The results are shown in Table 4.

The results confirm that the questionnaire has a high degree of stability, as the stability coefficients for the questionnaire domain ranged between 0.875 and 0.945, while the reliability coefficient for the questionnaire as a whole reached 0.947.

2.2. Statistical Methods.

(1) Pearson correlation coefficient was used to calculate the internal consistency/validity of the questionnaire.

(2) Alpha Cronbach coefficient was used to calculate the stability of the questionnaire.

(3) The arithmetic means and standard deviations were used to calculate the sample members' responses to the questionnaire and then estimate the agreement degree of the sample members with the questionnaire items and on each domain of the questionnaire [24].

(4) The Mann–Whitney test was used to find the significance of the differences between the sample members' responses according to the qualification variable.

(5) The Kruskal–Wallis test was used to find the significance of the differences between the sample members' responses according to the years of experience and the number of workshops in the VL field [24].

(6) The sample members' responses were estimated according to a five-point scale (1–5), and the average relative weight of the responses was calculated by dividing the range $(5-1=4)$ by the number of categories (5), meaning that the length of the category $= 0.8$, and then adding the length. The category for the smallest score on the scale, which is 1, the quantitative estimate of the sample members'

Table 1: Distribution of the sample according to the variables of academic qualification, years of experience, number of workshops in VLs.

Variables	Variable level	No	Percentage (%)
Academic qualification	Bachelor	45	83.3
	MD	9	16.7
Years of experience	Less than 5 years	9	16.7
	From 5 to 10	25	46.3
	More than 10 years	20	37
Number of workshops	Doesn't participate in any workshop	32	59
	1–2 workshops	15	28
	More than 2 workshops	7	13

responses, and the average relative weight of each response are shown in Table 5.

3. Results and Discussion

This section discusses the results of the four main and their subsidiary questions. The results were divided into four parts keeping in view the four domains of the questions. The main question of the first domain was: "What is the biology teachers' awareness degree of the importance of using VLs in developing higher thinking skills among secondary school students in Al-Kharj?". The answer to this question came through an analysis of the sample members' responses on the first domain of the questionnaire, which is given in Table 6.

The responses on almost all the items of the first domain came to a large extent, except for two items with a medium degree, and the approval of the domain as a whole came to a large degree and with arithmetic mean (3.8). The importance of using VLs in developing many higher thinking skills was supported by the responses. Also, the responses supported that the students should take responsibility for their learning and they should be encouraged to make decisions.

The responses of the teachers on this domain agreed with the results of many studies that had shown the effectiveness of VLs in developing practical skills [25] and conducting experiments in biology in particular [16], in addition to the positive effect of VLs on the development of various thinking skills.

The main question of the second domain was: "What is the degree of biology teachers' use of VLs in developing higher thinking skills for high school students in Al-Kharj?". The answer to this question came through an analysis of the responses on the second domain of the questionnaire, and the results are shown in Table 7.

The sample members' responses came to all the items of the second domain with a medium degree, except for one item on which the approval came to a large extent. The teachers' responses on this domain showed their great interest in stimulating the scientific curiosity of the students while conducting practical experiments, through various practices, including encouraging students to self-question themselves, asking the largest number of solutions while conducting experiments, thinking aloud, and training on the metacognitive skills. This result is consistent with the results of the study conducted by Elyan and Al-Ghatim [26], which showed the use of VLs with a moderate degree.

The answer to the third main question came through an analysis of the responses on the third domain of the questionnaire. The main question was: "What are the obstacles to using biology teachers for VLs in developing higher thinking skills among high school students in Al-Kharj?". The results are shown in Table 8.

The teachers' responses came on this domain in general to a large extent, and the responses to the items varied in terms of obstacles in the use of VLs in developing higher thinking skills, as the approval of some obstacles came to a very large degree, and the order of these obstacles came as follows:

(1) A large number of students in the class reduced my use of VLs.

(2) Increasing the teaching hours and the administrative tasks of the biology teacher prevents the use of VLs.

(3) Schools lack the necessary equipment to use VLs (the small number of computers, the weak and frequent disruptions of the Internet, etc.).

(4) There is a scarcity of VL programs that depend on the Arabic language.

(5) The lack of a female lab attendant qualified to deal with VLs restricted my use.

While the responses on 6 items largely came in the following order:

(1) The design of the software does not help the students to evaluate higher thinking skills, which prevented my use.

(2) The time required to teach the advanced biology curricula is not sufficient to use VLs.

(3) There is difficulty in customizing the virtual lab software to suit the needs of students according to the educational level.

(4) Poor skills needed to apply experiments using VLs for female students.

(5) The low motivation of students and their reluctance to conduct experiments affects the use VLs.

(6) The use of VLs was not linked to the performance evaluation that did not motivate me to use them.

The response was on one item, with a moderate degree, which is "My weakness in dealing with computers and its applications has limited my use of VLs."

Table 2: Correlation coefficients between the score of each item in the questionnaire and the total score of the domain to which it belongs.

First domain		Second domain		Third domain		Fourth domain	
No. of items	Correlation coefficient	No. of items	Correlation coefficient	No. of items	Correlation coefficient	No. of items	Correlation coefficient
1	0.840**	1	0.743**	1	0.542*	1	0.921**
2	0.852**	2	0.662**	2	0.449*	2	0.889**
3	0.857**	3	0.491*	3	0.814**	3	0.786**
4	0.762**	4	0.845**	4	0.726**	4	0.752**
5	0.637**	5	0.819**	5	0.466*	5	0.798**
6	0.831**	6	0.732**	6	0.730**	6	0.899**
7	0.837**	7	0.820**	7	0.792**	7	0.644**
8	0.734**	8	0.663**	8	0.679**	8	0.961**
		9	0.849**	9	0.723**	9	0.856**
		10	0.795**	10	0.480*		
		11	0.694**	11	0.710**		
		12	0.879**	12	0.792**		

*Significant correlation coefficient at a significance level of 0.05. **Significant correlation coefficient at a significance level of 0.01.

Table 3: The correlation coefficients between the score of each domain and the total score of the questionnaire.

The questionnaire domains	Correlation coefficient
Awareness of the importance of VLs in developing higher thinking skills	0.786**
Using VLs in developing higher thinking skills	0.82**
Obstacles to using VLs in teaching advanced biology curricula	0.797**
Requirements for using VLs in teaching biology curricula for developing higher-order thinking skills	0.608**

**Significant correlation coefficient at a significance level of 0.01.

Table 4: The stability coefficients of the questionnaire.

The questionnaire domains	Correlation coefficient
Awareness of the importance of VLs in developing higher thinking skills	0.917
Using VLs in developing higher thinking skills	0.926
Obstacles to using VLs in teaching advanced biology curricula	0.875
Requirements for using VLs in teaching advanced biology curricula to develop higher-order thinking skills	0.945
The whole questionnaire	0.947

These results are consistent with the obstacles shown by Elyan and Al-Ghatim [26]; Al-Juhani [6]; and Al-Ghaith [21].

The fourth question was: "What are the requirements for using biology teachers to the VLs in developing higher thinking skills among high school students in Al-Kharj?". This question was answered by analyzing the responses on the fourth domain of the questionnaire, and the results are shown in Table 9.

The responses on all the items of this domain came to a very large extent, as well as the response on the domain was a very large degree. Many requirements must be met in every school to allow the biology teachers' use for VLs in the development of higher thinking skills. The teachers expressed the importance of professional development programs informing them of the virtual reality program developments and qualifying female teachers to use VLs.

The results presented in this domain are consistent with the results and recommendations of many previous studies including Reda [22] and Al-Ahmed et al. [27].

To answer the question, "Are there statistically significant differences between the advanced biology curricula teachers' responses according to the Bachelor's/Master's qualification, years of experience, workshops in the virtual classes field?", the significance of the differences between the responses was verified depending on each variable separately.

(a) The significance of the differences between the sample members' responses according to the qualification variable (BA/MA).

To verify the significance of the differences between the sample members' responses according to the qualification variable, the Mann–Whitney test was used, and the results are shown in Table 10.

It is evident from the results that there are no statistically significant differences between the sample members' responses on all the domains of the questionnaire according to the scientific qualification variable.

Table 5: The quantitative estimate of the respondent's responses to the questionnaire.

Approval degree	Very large	Large	Medium	Low	Very low
Quantitative estimation	5	4	3	2	1
Average relative weight	4.2–5	3.4–4.19	2.6–3.39	1.8–2.59	1–1.79

Table 6: The sample members' responses on the first domain of the questionnaire.

No.	Awareness of the importance of VLs in developing higher thinking skills	Arithmetic mean	Standard deviations	Approval degree
1	Using VLs in teaching the advanced biology curriculum leads to the development of various higher thinking skills among students	4.09	0.83	Large
2	Using VLs in teaching the advanced biology curricula develops students' ability to solve problems	4	0.95	Large
3	The use of VLs in teaching the advanced biology curricula encourages students to make appropriate decisions	3.87	0.95	Large
4	I think that using VLs in teaching biology curricula does not provide students with higher-order thinking skills, as practicing in a traditional laboratory	2.96	1	Medium
5	Using VLs in teaching the advanced biology curricula holds students responsible for their learning	4.04	0.85	Large
6	VLs help the biology teacher to invest class time in developing the higher thinking skills of her students	3.83	1.09	Large
7	The use of VLs in teaching the advanced biology curricula provides opportunities to discover the creativity of students	3.83	1.04	Large
8	I feel that virtual lab programs in teaching advanced biology curricula do not help students connect imagination with reality	3	1.13	Medium
	The whole domain	0.99	3.70	Large

Table 7: The responses of the sample members on the second domain of the questionnaire.

No.	Using VLs in developing higher thinking skills	Arithmetic mean	Standard deviations	Approval degree
1	Apply higher-order thinking strategies while teaching the advanced biology curricula using VLs	2.98	0.6	Medium
2	Allow all students to conduct experiments by themselves using VLs	3.07	0.67	Medium
3	I encourage students while conducting experiments using VLs to propose as many solutions as possible	3.09	0.65	Medium
4	I provide opportunities for students to analyze and judge opinions and perspectives	3.13	0.65	Medium
5	While using VLs, I encourage students to reflect on their learning	3.43	0.79	Large
6	Training students to apply scientific thinking steps using VLs	3.17	0.64	Medium
7	Encourage students to think out loud while conducting experiments using VLs	2.98	0.94	Medium
8	I encourage students to ask self-questions (before-during-after) learning	3.13	0.73	Medium
9	Train students on metacognitive skills (planning-monitoring and control-evaluation) while conducting experiments using VLs	3.35	0.73	Medium
10	Use thought-provoking simulation software for VLs to teach various topics of the advanced biology curricula	3.19	0.68	Medium
11	Use constructive evaluation methods to measure the higher thinking skills of the students while they are using the VLs	3.11	0.77	Medium
12	Apply higher-order thinking strategies while teaching the advanced biology curricula using VLs	3	0.87	Medium
	The whole domain	3.12	0.72	Medium

(b) The significance of the differences between the sample members' responses according to the years of experience variable.

To verify the significance of the differences between the sample members' responses according to the years of experience variable, the "Kruskal–Wallis" test was used, and the results are shown in Table 11.

It is evident from the previous results that there are no statistically significant differences between the sample members' responses on all the domains of the questionnaire according to the years of experience variable.

(c) The significance of the differences between the sample members' responses according to the number of workshops in the VL field variable.

Table 8: The sample members' responses on the third domain of the questionnaire.

No.	Obstacles to using VLs in teaching advanced biology curricula	Arithmetic mean	Standard deviations	Approval degree
1	Poor skills needed to apply experiments using VLs for female students	3.8	0.98	Large
2	Schools lack the necessary equipment to use VLs (few computers, weak and frequent Internet disruptions, etc.)	4.54	0.75	Very large
3	The scarcity of virtual lab programs that rely on the Arabic language	4.46	0.72	Very large
4	Low motivation and reluctance of female students to conduct experiments using VLs	3.69	1.11	Large
5	Increasing the teaching hours and administrative burdens on the biology teacher prevents the use of VLs	4.59	0.71	Very large
6	The lack of qualified lab equipment to deal with VLs limited my use of them	4.24	0.99	Very large
7	A large number of students in the class reduced my use of VLs	4.65	0.68	Very large
8	The design of the software does not help the students to evaluate higher thinking skills which prevented me from using it	4.06	0.94	Large
9	My poor skills in dealing with computers and their applications limited my use of VLs	3.15	0.98	Medium
10	The difficulty of customizing the virtual lab software to suit the needs of students depending on the educational level	3.94	0.83	Large
11	Not linking the use of VLs to my performance evaluation did not motivate me to use them	3.31	1.18	Large
12	The time required to teach the developed biology curricula is not sufficient to use VLs	4	0.91	Large
	The whole domain	4.04	0.89	Large

Table 9: The respondents' responses on the fourth domain of the questionnaire.

No.	Requirements for using biology parameters for VLs in developing higher thinking skills	Arithmetic mean	Standard deviations	Approval degree
1	Providing the infrastructure in schools to use VLs (computerized labs, fast Internet connection, etc.)	4.46	0.82	Very large
2	Professional development: providing training programs for in-service biology teachers on how to apply VLs and use them to develop higher-order thinking skills for students	4.33	0.85	Very large
3	Informing the advanced biology teachers about the latest developments in virtual reality programs and their uses in developing students' thinking skills	4.33	0.87	Very large
4	Academic preparation: biology teachers in colleges of education should be prepared on strategies for higher thinking skills and how to apply them while using VLs in science teaching	4.43	0.72	Very large
5	Providing computers with special specifications to more clearly represent complex scientific phenomena	4.5	0.8	Very large
6	Providing a trained and qualified lab teacher to operate and equip the virtual lab in the school	4.54	0.79	Very large
7	The existence of a clear plan and guidelines by the Ministry of Education to use virtual classrooms in teaching the advanced biology curricula	4.35	0.87	Very large
8	Providing codified constructive evaluation tools to evaluate higher-order thinking skills, evaluate the performance of students, and guide them while using VLs	4.35	0.8	Very large
9	Providing simulation programs in Arabic language, data analysis, and visual presentation	4.52	0.67	Very large
	The whole domain	4.42	0.80	Very large

To verify the significance of the differences between the sample members' responses according to the number of workshops in the VL field variable, the "Kruskal–Wallis" test was used, and the results are shown in Table 12.

It is evident from the results that there are statistically significant differences at the level of significance ($\alpha \leq 0.05$) between the sample members' responses according to the number of workshops in the VLs field variable awareness of using VLs importance and the degree of using VLs. There are no statistically significant differences regarding the obstacles to using the VLs and the requirements for using the VLs.

To identify the direction of the differences between the sample members' responses on the first and second domains, the Mann–Whitney test was used to make comparisons

Table 10: The significance of the differences between the sample members' responses according to the scientific qualification variable.

Questionnaire domains	Scientific qualification	Sum of the order	Mean of the order	Z value	Significance level	Significance
Awareness of the importance of using VLs	Bachelor MD	1155.5 329.5	25.68 36.61	1.913	0.056	Not significant
The degree of using VLs	Bachelor MD	1288 197	28.62 21.89	1.177	0.239	Not significant
Barriers to using VLs	Bachelor MD	1287 198	28.60 22.0	1.155	0.248	Not significant
Requirements for using VLs	Bachelor MD	1167 318	25.93 35.33	1.67	0.093	Not significant

Table 11: The significance of the differences between the sample members' responses according to the years of experience variable.

Questionnaire domains	Years of experience	Order means	Freedom degree	K Square	Significance level	Significance
Awareness of the importance of using VLs	Less than 5 years From 5 to 10 years More than 10 years	28.44 25.08 30.10	2	1.182	0.554	Not significant
The degree of using VLs	Less than 5 years From 5 to 10 years More than 10 years	33.33 25.86 26.93	2	1.549	0.461	Not significant
Barriers to using VLs	Less than 5 years From 5 to 10 years More than 10 years	28.1 1 25.36 29.90	2	0.951	0.621	Not significant
Requirements for using VLs	Less than 5 years From 5 to 10 years More than 10 years	21.61 26.34 31.60	2	2.897	0.235	Not significant

Table 12: The significance of the differences between the sample members' responses according to the number of workshops in the VL field variable.

Questionnaire domains	Number of workshops	Order means	Freedom degree	K Square	Significance level	Significance
Awareness of the importance of using VLs	Don't participate in any workshops From 1-2 More than two workshops	20.75 38.47 34.86	2	14.865	0.001	Significant
The degree of using VLs	Don't participate in any workshops From 1-2 More than two workshops	22.44 32.93 39	2	8.921	0.012	Significant
Barriers to using VLs	Don't participate in any workshops From 1 to 2 More than two workshops	25.86 27.77 34.43	2	1.728	0.422	Not significant
Requirements for using VLs	Don't participate in any workshops From 1 to 2 More than two workshops	26.81 27.70 30.21	2	0.286	0.867	Not significant

Table 13: The direction of the differences between the sample members' responses on the awareness domain of the importance of using VLs according to the number of workshops in the VL field variable.

Questionnaire domains	Number of workshops	Sum of the order	Mean of the order	Z value	Significance level	Significance
Awareness of the importance of using VLs	Don't participate in any workshops	609.5	19.05	0.429	0.668	Not significant
	From 1-2	518.5	34.50			
Awareness of the importance of using VLs	Don't participate in any workshops	582.5	18.20	2.11	0.034	Significant
	More than two workshops	197.5	28.21			
Awareness of the importance of using VLs	From 1 to 2	178.5	11.90	3.63	0.00	Significant
	More than two workshops	74.50	10.64			

Table 14: The direction of differences between the sample members' responses on the degree of using the VL domain according to the number of workshops in the VL field variable.

Questionnaire domains	Scientific qualification	Sum of the order	Mean of the order	Z value	Significance level	Significance
Degree of using the VLs	Don't participate in any workshops	674	21.06	2.158	0.031	Significant
	From 1-2	454	30.27			
Degree of using the VLs	Don't participate in any workshops	572	17.88	2.50	0.012	Significant
	More than two workshops	208	29.71			
Degree of using the VLs	From 1 to 2	160	10.67	0.377	0.407	Not significant
	More than two workshops	93	13.29			

between the study groups so that the comparison between every two groups could be made separately, and the results are shown in Table 13.

It is evident from the results that there are statistically significant differences at the significance level ($\alpha \leq 0.05$) between the sample members' responses concerning the awareness level of the importance of using the default laboratories, depending on the number of workshops in the VL field variable, between the teachers who participated in more than two workshops and the teachers who participated in one or two sessions for the benefit of the teachers who participated in more than two workshops, and between the teachers who participated in more than two workshops and the teachers who did not participate in any workshop for the benefit of the teachers who participated in more than two workshops. They are no statistically significant differences between the teachers who did not participate in any workshop and the teachers who participated in one or two workshops.

It is clear from the results (Table 14) that there are statistically significant differences between the sample members' responses concerning the degree of using the VLs, depending on the number of workshops in using the default laboratories variable between the teachers who did not participate in any workshop and the teachers who participated in one or two workshops. There were no statistically significant differences in the teachers' responses who participated in one or two workshops and the ones who participated in more than two workshops.

4. Discussion and Conclusion

Using technology-based learning and teaching is always of great importance. Teachers are always searching for finding new methods for teaching the materials in the classroom effectively and successfully. Thus, this study is unique since after reviewing the previous studies, and it was revealed that no study has been performed in Saudi Arabia to check the reality of using virtual labs in teaching advanced biology curricula in developing HOTS among female teachers at the secondary level.

The results of the answer to this question can be explained in light of the importance of training workshops in raising awareness of the importance of VLs, and the degree of using the VLs, given that these workshops focus on the practical, performance aspect, which is lacking in academic preparation programs that are concerned with the theoretical side. It may be devoiced of focus on technological innovations and their employment in the educational process, which also explains the absence of differences between the sample members' responses according to the scientific qualification variable.

Using virtual labs (VLs) to teach advanced biology curriculum and foster the development of higher-order thinking skills (HOTS) among female secondary school students in Saudi Arabia's Al-Kharj area was the goal of this project. The research was carried out in a descriptive fashion. In Al-Kharj, 54 female secondary school biology teachers completed a questionnaire with four dimensions: awareness of the importance of virtual laboratories in developing higher-order thinking skills, use of virtual laboratories in developing higher-order thinking skills, obstacles to the use of virtual laboratories in teaching advanced biology curricula, and requirements for the use of virtual laboratories in teaching advanced biology. As a result of the research, it became clear that using VLs to build higher-order thinking abilities at a big degree, as well as utilizing VLs at a medium level of education, would be difficult, as well as the prerequisites for using VLs in biology classes to accomplish this goal. There were statistically significant variations in the reactions of female teachers to the frequency of training sessions held in VLs. In terms of academic degrees and years of experience, there were no statistically significant differences. A student's laboratory abilities may be improved by the use of a virtual teaching and learning environment, which is referred to as a "virtual lab." As one of the most significant tools for eLearning, virtual laboratories enable students to perform a variety of experiments without being limited by time or location, in contrast to the limits that are present in traditional lab settings. Students are able to conduct a wide variety of experiments using virtual laboratories, many of which would be too dangerous to carry out in traditional laboratories. Teachers and students may save time and effort by using virtual laboratories since they do not have to stick to certain hours in order to access the lab or to transfer from one location to another. This allows for more flexibility.

These findings are significant from a cognitive standpoint when it comes to learning science since they demonstrate that students are able to build on previously acquired ideas and information. The current research acknowledges that, when used in the right context, instructional technology may help students learn more effectively. The many components of adopting instructional technology may engage and play a fundamental part in assisting students in achieving better results by supporting innovative teaching and learning methodologies. This underlines the need of incorporating web-based learning into a variety of classroom settings. Studies conducted in the past corroborate these conclusions [28, 29]. Based on this information, it should be noted that V-Lab had a considerable impact on fourth-grade science students. The use of computer-simulated experiments might help students become more engaged in the learning process and better grasp scientific topics, according to some academics [28, 30].

5. Recommendations

Based on the results of the study, the following recommendations and suggestions can be made:

(1) There is a need to reconsider the infrastructure of information technology in different schools for all school levels, in a way that suits the use of technological innovations in the educational process, especially VLs in the field of teaching and learning biology. There is also a need to provide appropriate software in the Arabic language to achieve the abovementioned goal.

(2) Some programs must be developed to help biology teachers develop their expertise. There should be a special focus on employing VLs in conducting practical experiments in all fields of science.

(3) Teaching hours for biology teachers should be reduced so that they can pay attention to the practical aspect of teaching and learning biology.

(4) More training workshops must be held for biology teachers regarding VLs particularly.

(5) Similar research studies must be conducted to assess the present state of various technological innovations in teaching and learning sciences at various school levels.

(6) similar study can be carried out on male teachers to check the reality of using virtual labs in teaching advanced biology curricula in developing HOTS.

(7) Other levels of proficiencies can be considered in the next studies.

(8) In next studies, the attitude of learners toward using virtual labs in teaching advanced biology curricula in developing HOTS can be considered.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] R. A. Al-Mihi and 1. M. Nagla, *Science Education and Technology Education*, Dar Al-Aqsa Printing, Talkha, Egypt, 2005.

[2] A. A. Al-Shehri, "A proposal for designing a virtual laboratory in developing scientific thinking in the Physics course for high school students in Al-Baha Region," *The Scientific Journal of the Education Faculty*, vol. 34, no. 8, pp. 175–207, 2018.

[3] S. A. Balfakih, "Obstacles to the use of virtual laboratories for natural sciences teachers at the secondary stage in the city of Mukalla," *Journal of Human and Applied Sciences*, vol. 3, no. 2, pp. 237–272, 2020.

[4] R. Howlett and V. Uskov, "Smart education and e-learning," 2020, https://books.google.com/books.

[5] B. F. Woodfield, M. B. Andrus, T. Andersen et al., "The virtual chem lab project: a realistic and sophisticated simulation of organic synthesis and organic qualitative analysis," *Journal of Chemical Education*, vol. 82, no. 11, p. 1728, 2005.

[6] A. R. Al-Juhani, "Obstacles to using virtual laboratories in the teaching of science at the secondary stage in the Al-Madinah Al-Munawwarah region from the supervisors and teachers' point of view and their attitudes towards it," *Arab Studies in Education and Psychology*, vol. 44, no. 2, pp. 161–190, 2013.

[7] D. Yaron, J. Cuadros, K. Leinhardt, K. L. Evans, and M. Karabinos's, "Virtual Laboratories and Scenes to Support Chemistry Instruction Lessons Learned," 2005, https://www.researchgate.net/publication/237525891_Virtual_Laboratories_and_Scenes_to_Support_Chemistry_Instruction_Lessons_Learned.

[8] N. M. Anter, "The role of virtual experiments in appling the principles good practice in teaching," in *Proceedings of the International Conference One-Learning and Distance Learning Ministry Higher Education*, Riyadh, Saudi Arabia, 2009.

[9] A. S. Ahmed, "The effect of using the virtual laboratory in the achievement of physical concepts and the acquisition of higher thinking skills and motivation towards learning science among third-year middle school students," *The Egyptian Journal of Scientific Education*, vol. 13, no. 6, pp. 1–46, 2010.

[10] A. Al Musawi, A. Ambusaidi, S. Al-Balushi, and K. Al-Balushi, "Effectiveness of E-lab use in science teaching at the Omani schools," *Turkish Online Journal of Educational Technology-TOJET*, vol. 14, no. 1, pp. 45–52, 2015.

[11] M. A. Al-Hafiz and A. Johar, "The virtual laboratory for physics and chemistry experiments and its impact on the development of observation power for middle school students and their cognitive achievement," *The Arab Journal of Educational and Social Studies*, vol. 2, pp. 7–31, 2013.

[12] A. M. Al-Shehri, *The Effect of Using Virtual Laboratories in Imparting Laboratory Experiments Skills in the Biology Course for Third-Grade Secondary Students in Jeddah*, Umm Al-Qura University, Mecca, Saudi Arabia, 2009.

[13] A. H. Hazaa and I. M. Qutb, "The effectiveness of using virtual labs in academic achievement of high school students in physics course in Jeddah governorate, Kingdom of Saudi Arabia," *Majma'a Magazine: Al-Madinah International University*, vol. 33, pp. 328–386, 2020.

[14] Z. Tatli and A. Ayas, "Effect of a virtual chemistry laboratory on students' achievement," *Educational Technology and Society*, vol. 16, pp. 159–170, 2013.

[15] I. A. Hegazy, "Effectiveness of using virtual laboratories in the achievement and development of laboratory skills in chemistry among first-grade secondary students," *Journal of the College of Education at Port Said University*, vol. 3, no. 2, 2011.

[16] A. H. Al-Radi, *The Effect of using Virtual Laboratory Technology on the Achievement of Third-Grade Secondary Students*, King Saud University, Riyadh, Saudi Arabia, 2008.

[17] H. H. Zaiton, *A New Vision in E-Learning: Concept-Issues-Application-Evaluation*, Dar-AlSawtiah for Publishing and Distribution, Amman, Jordan, Western Asia, 3rdEdition, 2005.

[18] S. M. Nikoonezhad and A. Esfahani, "Identifying the barriers upon development of virtual education in engineering majors," *Journal of Education and Practice*, vol. 6, pp. 103–111, 2015.

[19] I. F. Rizk, "Designing a virtual laboratory in the science subject to develop the skills of using the laboratory and critical thinking skills for third-year middle school students and measuring its effectiveness," *Journal of Educational and Social Studies*, vol. 25, no. 6, pp. 279–324, 2019.

[20] G. D. Perkins, "The status of the science lab," *Educational Leadership*, vol. 64, no. 4, pp. 93-94, 2007.

[21] G. G. Al-Ghaith, "Intermediate-level science teachers' use of virtual laboratories and their attitudes towards them," *Specialized International Educational Journal*, vol. 6, no. 5, pp. 39–53, 2017.

[22] H. S. Reda, "The effectiveness of using the investigative and illustrative virtual laboratory in teaching chemistry on the development of scientific thinking among students of the College of Education," *The Egyptian Journal of Scientific Education*, vol. 13, no. 6, pp. 61–106, 2010.

[23] A. I. Al-Madhi, *Problems of Teaching Science Curricula Developed in Elementary Level and Proposals for Solving them from the Viewpoint of Science Teachers Al-Qassim Region*, Al-Qassim University, Buraydah, Qassim, Saudi Arabia, 2012.

[24] A. Abdulrahman Alshaikh, "A proposal for developing the performance of intermediate second-grade students in science tests in trends in international mathematics & science study (TIMSS)," *Journal of Education and E-Learning Research*, vol. 8, no. 1, pp. 26–33, 2021.

[25] C. Tuysuz, "The effect of the virtual laboratory on students' achievement and attitude in chemistry," *International Online Journal of Educational Sciences*, vol. 2, pp. 37–53, 2010.

[26] S. R. Elyan and M. A. Al-Ghatim, "Training needs for using the virtual laboratory from the viewpoint of science teachers in Al-Ahsa governorate," *The Arab Gulf Message, Arab Bureau of Education for the Gulf States*, vol. 39, no. 147, 2017.

[27] N. A. Al-Ahmed, M. Omar, S. H. Haj, and A. F. Suleiman, "The level of achieving the educational specifications in the student's books of biology, physics, and chemistry for the first grade of secondary school, with the series of McGraw Hill books," *Journal of Al-Quds Open University for Research and Educational and Psychological Studies*, vol. 5, no. 18, pp. 17–33, 2017.

[28] M. D. Koretsky, D. Amatore, C. Barnes, and S. Kimura, "Enhancement of student learning in experimental design using a virtual laboratory," *IEEE Transactions on Education*, vol. 51, no. 1, pp. 76–85, 2008.

[29] T. Way, "A virtual laboratory model for encouraging undergraduate research," in *Proceedings of the 37th SIGCSE Technical Symposium on Computer Science Education*, pp. 203–207, Houston, TX, USA, 2006.

[30] K. Y. Yang and J.-S. Heh, "The impact of internet virtual physics laboratory instruction on the achievement in physics, science process skills and computer attitudes of 10th-grade students," *Journal of Science Education and Technology*, vol. 16, no. 5, pp. 451–461, 2007.