

Effectiveness of Learning with 3D-Lab on Omani Basic Education Students' Achievement, Attitudes and Scientific Thinking

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Abstract

This paper aims to measure the effectiveness of the 3DL on Omani students' acquisition of practical abilities and skills. It examines the effectiveness of the 3D-lab in science education and scientific thinking acquisition as part of a national project funded by The Research Council. Four research tools in a Pre-Post Test Control Group Design, findings show statistically significant differences in student achievement in favor of the experimental group. The results show students' attitudes are positive towards using 3D-lab in teaching. Improvements in logical and visual thinking are also observed. The paper then draws conclusions and recommendations.

Keywords: 3D-lab, Oman, science education, attitude, basic education, logical thinking, visual thinking

1. Introduction

1.1 The Problem

The strategies used as part of the traditional school settings have certainly not addressed the educational requirements in this information age. To accomplish the scientific and lifelong learning objectives, we need to implement new methods and techniques taking advantage of the technological developments and innovative practices. Innovative applications have influenced the academic community members and instructional materials and mechanisms. They have become an essential part of the teaching and learning process. For example, science educators can benefit from the use of 3D simulations during their lab work and practical lessons.

The study aims to investigate the effectiveness of the 3DL in teaching science with a set of cognitive variables particularly academic achievement, logical thinking, and visual thinking among fourth graders in the Omani basic education schools. In addition, the study aims to identify advantages and impediments of using 3DL in the Omani basic education schools.

1.2 Importance of the Problem

This study is important specifically for the Omani educational system because the students need to get practical and mental skills in using 3DL in their science lessons and their teachers need to be encouraged to apply new educational technologies in their daily practical work. They must build up the scientific thinking skills and procedures among students using active electronic and interactive tools. The study inspires them to find out about the effectiveness of these lab tools and develop inquiry based learning their science lessons. It is equally important to develop students' attitudes toward science and lab work in basic education in Oman.

1.3 Relevant Scholarship

Integrating innovations and technologies in teaching and learning is no longer an extra tool in a classroom. It has become a prerequisite for the foundation of an effective educational infrastructure as it provides a dynamic and lively experience for learners. For example, e-Learning has become indispensable in people's lives and applications, since mobile, portable, and virtual learning have started (Sharples, Amedillo, Milrad & Vavoula, 2007). The utilization of these technologies infers extraordinary impact on schools, students and science. They allow controlling situations that are hard to experiment in old-fashioned classroom settings and implementing numerous unsafe experiments through

virtual reality. We will now survey research accounts on ideas, definitions, implications, types, and impediments of 3D-labs (later, 3DL).

1.3.1 Definition Objectives of 3DL

Science education is strictly related to experimental practices and practical work. Current literature approves the vital role of experimentation in broadening the learners' dynamic involvement in the learning process along with the idea of developing their diverse aptitudes and shaping their positive dispositions towards science education (ICSU, 2011). Laboratories designers have concentrated their thoughts to use computer applications that produces a safe, active, and collaborative learning setting and simulates realistic 3DL. This lab may be defined as "one where the student interacts with an experiment or activity which is intrinsically remote from the student or which has no immediate normal reality" (Hatherly, n. d.; Al Musawi, Ambusaidi, Al-Balushi & Al-Balushi, 2015). It can be described as a tool consists of interactive computerized software linked with sensitive connector endings called sensors, where the components of practical sciences experiments are integrated with computers as a measurement instrument to collect and analyze data (Al-Shaiey, 2006; Al Musawi et al. 2015).

3DL is used with the aim to improve the normal lab work and keep pace with the technological developments, utilizing computer-programming abilities to construct educational experiences and practices. Science teachers can fill in for the traditional lab equipment/tools' defects by using 3D software where it helps learners to profoundly comprehend science ideas and resolve their preconceived scientific misunderstandings. 3DL can be used aiming to form and improve learners' positive attitudes towards science and technology (Shaheen & Khattab, 2005, p. 206; Al Musawi et al. 2015).

1.3.2 Components and Types of 3DL

Al-Bayati (2006) specifies that 3DL comprises of main components such as laboratory tools including various old-style laboratories with few improvements to help in their application inside the lab and 3DLs. The latter are provided with computers, laptops, or tablets linked to the school servers and Internet to enable the students to work in the lab or distantly whenever or wherever they want to get to the system. The computers and servers must have the lab software and simulation programs that permit their interaction with the virtual experiments. The communication system operates when all the clients are working remotely with the 3DL to conduct an experiment, the whole system interface ought to be associated with their computers and servers and the communication channels should be profoundly secured and reliable as required by the experiment. It is important to supply these labs with reasonable cost keeping in mind the end goal to set up communication between the clients and the 3DL in which they can carry out all the required experiments 3DL software (pp. 28-32).

There are two types of 3DL software. One teaches the client to figure out how to conduct experiment giving them the required data. The other controls the lab by integrating special 3DL, simulation programs and preliminary training of the clients on the most proficient method to implement the system effectively. The participation and management software includes how to administer the lab and the clients' involvement. This software enlists the clients and decides access types they can get to work in different experiments. The significance of such software lies in their capacity to enable each participant group to conduct the experiment as indicated by specific levels, for example, enabling them to work at a specific stage on few investigations and tools that suit them (Al-Shahri, 2009, p. 72; Al Musawi et al. 2015).

Based on the above, there are different types of 3DL. The first are the 'computerized science labs'. These are two-dimensional labs depend on sensors for testing and performing analyses. They incorporate the design of various lab's experiments that are accessible to the client on the computer or saved on DVDs and CDs. This type does not provide the learner with the required level of engagement into the virtual environment. The second type are 'online simulation labs', which are normal two-dimensional labs that include experiments and offer various investigations and analyses in short video formats. This system is accessible on the Internet so anybody can see and control them. Notwithstanding, the level of the students' involvement with the experiment and their capacity to transform them is restricted. The third type are 'electronic labs' that provide practical experiences and analyses closer to certainty. The system is introduced in two-or-three dimensional formats associated with by sound, image and movement. Their electronic environments are adjustable and manageable. They offer a great deal of interaction between the clients and 2D or 3D settings and allow more than one client to explore the lab and communicate with others. The fourth type is '3DLs', which are virtual reality software of true experiments. They are similar to the electronic labs described in type three above yet they utilize new advanced gadgets such as goggles, head-mounted displays, gloves, and tracking system and enable the client to participate in an enriched virtual reality environment with physical interaction of the eyes, ears and hands. Efforts keep on involving all parts of the client's body through a full body dress that links senses and brain zones with feedback controllers to achieve immediate contact with the skin surface of the client bringing about an entire human contact with virtual reality exploration (Zaitun, 2002, p. 165; Farooq et al, 2013; Al Musawi et al. 2015).

1.3.3 Pros and Cons of 3DL Use

3DL is a progressive technologic method in the field of science education through which the learner uses computers not just as an instrument for data keeping or processing but also as a lab for estimation and control. Additionally, it turns into an instrument to reflect and decide on experiments in connection to hypotheses so the students can comprehend their importance. They can utilize the 3DL as a way to find the laws through actual measurements while doing these experiments. They can see how chemical compounds are made and how they work (Al-Balushi & Al-Hajri, 2014). In this way, 3DL fills in as a device to recognize and persuade through review, experimentation and conclusion (Al Musawi et al. 2015).

Zaitun (2002) reports that 3DL can be an excellent replacement for conventional lab as it offers learners with experiences similar to direct ones while resolving impediments that may hinder conducting real experiments. It also allows students to interact with attractive and dynamic scientific situations and manage their practical analysis with instantaneous feedback (p.164). In addition, 3DL advances educational program by furnishing learners with experiences that would be excessively unsafe or restrictively costly in a traditional setup. It can utilize interesting visual representations that support deep understanding of phenomena not directly observable or accessible in traditional labs (Coble et al. 2010; Al Musawi et al. 2015).

The virtual labs are generally limited by the need to operate by computers and hardware with efficient technical specifications for clear depiction of multifaceted phenomena. In addition, specialists from different branches of science such as programming, curriculum and psychology must be employed to design and produce them. 3DLs production should be contextualized culturally in terms of students' language and content, a case applied to the Omani setting where the medium of instruction is Arabic (Al Musawi et al. 2015).

1.3.4 Previous Studies in the Arab World

Experimental research conducted in the Arab World on electronic and virtual labs and resulted in a better students' academic achievement of scientific concepts in favor of the group that studied using these labs (Al-Mutairi, 1998; Al-Anzi, 2003; Al-Shannaq et al., 2004; Shabbat, 2005; Al-Shaiey, 2006; Al-Radi, 2008). In addition, the achievement means in levels of memorization, understanding, and application were all in favor of the experimental group (Al-Qarni, 2006). In Al-Shaiey study (2006), the results showed that the majority of the teacher sample (62 percent) used the electronic labs once at least during the semester. The study also showed positive attitudes between these teachers and their students towards using the electronic laboratories (Al Musawi et al. 2015).

Saleh, Al-Hadi & Al-Qadhi (2004) indicated the effectiveness of virtual lab especially when utilized alone to accomplish the lessons' objectives in terms of acquiring laboratory skills. Al-Khalaf study (2005) attributed to the impact of interaction between teaching method and gender in the achievement and skills tests to the use of virtual lab. Both Redha (2010) and Ahmad (2010) pointed out the effectiveness of the virtual lab investigating and demonstrating part in developing scientific thinking in addition to increasing the achievement in academic concepts. In Oman, Al-Balushi (2009) study revealed better post-test academic achievement and practical skills in favor of the group that studied using the virtual lab. The post-test also demonstrate positive attitudes towards this lab among the Omani students.

In light of the above reviewed research, this paper focuses on methods and procedures used to plan this investigation as part of a national project funded by The Research Council and aims to measure the effectiveness of the 3DL on Omani students' acquisition of practical abilities and skills (Al Musawi et al. 2015).

1.4 Study Questions

1. What effect does the 3DL have on Omani fourth graders' achievement?
2. What are the attitudes of Omani fourth graders towards the use of 3DL in science education?
3. What effect does the 3DL have on developing and acquiring logical and visual thinking by the Omani fourth graders?

2. Method

This study followed a quantitative method, particularly experimental research, to measure the effectiveness of the 3DL towards the following cognitive variables:

- academic achievement
- science processes
- scientific attitudes
- estimation of classroom environment

- practical skills
- visual thinking
- attitudes towards 3DL.

2.1 Research Design

The study investigates the effectiveness of the use of 3DL in science education, the acquisition of practical skills, and basic education learners' attitudes towards classroom environment and using 3DL lab in their learning. The following subsections include description of the participants or subjects and a section describing the procedures used in the study. In addition to the research design.

2.2 Participants

This study applied experimental design, namely, "Pre-Post Test Control Group Design". In this design, each of the experimental and control groups consisted of 30 students who went through academic achievement tests.

2.3 Research Tools

To achieve the study objectives, the following tools and scales were used:

1. Academic Achievement test: subject teachers prepared this test according to the lessons' plans. Its questions covers most of the scientific topics learned by both groups' students. The total score is used to calculate learners' science ability. The test is completed and corrected, and the teachers recorded scores for both groups' students.
2. Logical thinking scale: a standardized scale from Al-Hadhrami & Ambusaidi (2012). It was used to measure the logical thinking of Omani twelfth graders, similar grade level to this study's sample, with 0.72 reliability coefficient.
3. Visual thinking scale: a standardized scale from Al-Balushi & Al-Hajri (2014) to investigate the effectiveness of the 3DL in developing visual thinking.
4. Attitudinal scale: this is a standardized scale towards 3DL adopted from Al Balushi (2009) study. It includes negative and positive statements, with three answers' options: agree, neutral, and disagree. Positive statements are scored as (1,2,3); whereas negative statements are scored reversely (3,2,1).

2.3.1 The 3D lab

The 3DL used is called Eureka® which consists of collection of 3D animated and interactive instructional Arabic/English units in biology, physics and chemistry. The unit's materials adapted to the Omani science curriculum and suitable for the fourth basic education class were selected. The students watched the lessons during their learning used goggles. In addition, students used thirty tablets (Samsung® Galaxy Note) for the activities and interactions with the lessons.

2.3.2 Experimental Interventions

This study applied experimental design, namely, "Pre-Post Test Control Group Design". The experimental group was exposed to experimental treatment by learning through the 3DL. The teachers participated in the experiment after training to use the virtual lab and selection of science lessons. The experimental group's students used tablets to plug in to the 3D lab software and Internet while carrying out the experiments during the lessons under teacher supervision. Then, both the experimental and control groups took achievement and practical tests. Table (1) is a summary of the experimental interventions. It shows the Pretest and Posttest treatments given for both experimental and control groups along with the experimental treatment given to the experimental group. The control group used the traditional teaching methods.

Table 1. Experimental Interventions

Group	Pretests	Experimental Treatment	Posttests
Experimental	achievement test	use 3D-lab in teaching	achievement test
	logical thinking		logical thinking
	attitudinal scale towards 3D-lab		attitudinal scale towards 3D-lab
	visual thinking scale		visual thinking scale
Control	achievement test	use traditional methods in teaching (no 3D-lab)	achievement test
	logical thinking		logical thinking
	attitudinal scale towards 3D-lab		attitudinal scale towards w3D-lab
	visual thinking scale		visual thinking scale

3. Results

3.1 Achievement

To answer the research question: “What effect does the 3DL have on Omani fourth graders' achievement?”; improvement of experimental and control groups' achievement average scores in pre and posttests is calculated using t-test of the (Paired-Samples-t- Test); as shown in the Table (2).

Table 2. Means, standard deviations, and (t) value of experimental and control groups' achievement average scores in pre and posttests

Test levels	Group	Test type	Means	Standard Deviations	df	t	Sig
Knowledge	Experimental	Pre	3.31	1.53	26	6.24	0.001*
		Post	5.11	1.98			
	Control	Pre	3.83	1.39	26	5.88	0.001*
		Post	5.61	2.31			
Application	Experimental	Pre	6.11	3.99	26	0.30	0.771
		Post	6.26	3.13			
	Control	Pre	4.76	3.49	26	2.66	0.031*
		Post	6.07	3.93			
Metacognitive abilities	Experimental	Pre	3.11	1.79	26	5.40	0.001*
		Post	4.65	1.85			
	Control	Pre	2.24	1.50	26	6.71	0.001*
		Post	4.17	2.32			
Overall sum	Experimental	Pre	12.54	6.76	26	4.96	
		Post	16.02	6.01			
	Control	Pre	11.02	5.41	26	5.75	0.001*
		Post	15.85	8.10			

*Significance at ($\alpha \leq 0.05$)

Table (2) shows that there is improvement in the achievement test of both experimental and control groups, but the degree of improvement levels of the experimental group's students may be better than the control group's students as a result of their teaching with 3DL. Statistically significant differences can be observed in favor of the post application for the experimental group in the achievement test as a whole as well as for the two levels of knowledge and metacognitive abilities. No statistically significant difference is found for the application level.

To identify the effect size of using 3DL on achievement improvement of the experimental group's students, η^2 using the equation $\eta^2 = t^2 / (t^2 + df)$, was calculated; where (t) is the value of (t) of the overall sum, and (df) is the degrees of freedom; as shown in Table (3).

Table 3. (η^2) value and the effect size of using 3DL on the achievement improvement of the experimental group

Independent variable	Dependent variable	η^2	Effect size
Using 3DL	Achievement improvement	0.486	large

Table (3) shows that the effect size of using 3DL for the study sample is large. (49%) of the total variation of the dependent variable (achievement test improvement levels) is due to the effect of the independent variable (using the 3DL). This percentage is higher than the one set by Cohen (15% or more), in order to consider the effect size of the independent variable on the dependent variable as large.

3.2 Attitudes

To answer the research question: “What are the attitudes of Omani fourth graders towards the use of 3DL in science education?” frequencies and percentages of the experimental group responses according to their attitudes towards 3DL were calculated as shown in the Table (4).

Table 4. Frequencies and percentages of the experimental group responses according to their attitudes towards 3DL*

Items	Agree		Not Sure		Disagree	
	Freq.	%	Freq.	%	Freq.	%
Work in the 3DL worrying and tiresome.	-	-	-	-	26	100%
Learning science through 3DL is exciting and interesting	25	96.2%	-	-	-	-
3DL focuses on learning through observation, deduction, inquiry, and exploration thus enhancing my scientific knowledge.	22	84.6%	2	7.7%	2	7.7%
I like the conducting practical experiments and procedural activities through 3DL.	26	100%	-	-	-	-
3DL helps me to form accurate mental images about the learning subject.	23	88.5%	3	11.5%	-	-
I like the idea of having an integrated 3DL using the computer tablet.	24	92.3%	-	-	2	7.7%
I like the 3DL form and design that include the contents of interesting scientific materials and tools.	24	92.3%	1	3.8%	1	3.8%
I like the diversity, design accuracy, and ease of use of scientific lessons, activities and instruments in the 3DL library.	25	92.2%	-	-	1	3.8%
I do not feel the time goes when conducting practical experiments in the 3DL.	17	65.4%	5	19.2%	4	15.4%
I can make practical experiments and record my observations and results in a calm atmosphere.	21	80.8%	1	3.8%	4	15.4%
I do not like making practical experience using 3DL	6	23.1%	-	-	19	73.1%
I see that the 3DL provide me with new skills and develop my practical performance in laboratory experiments.	24	92.3%	1	3.8%	1	3.8%
I feel confident when conducting practical experiments using the 3DL.	22	84.6%	2	7.7%	2	7.7%
I feel that I am interactive learner while using the 3DL rather than being a recipient of the information only.	24	92.3%	1	3.8%	1	3.8%
3DL tools help me to assess my laboratory skills independently.	25	96.2%	1	3.8%	-	-
I like the idea of self-learning through 3DL.	23	88.5%	-	-	3	11.5%
I feel happy and enthusiastic when conducting practical experiments through 3DL more than I do with the traditional lab.	23	88.5%	2	7.7%	1	3.8%
I can continue making practical experiments and taking notes at my pace of learning.	20	76.9%	3	11.5%	3	11.5%
I do not need the presence of a technician when using 3DL to do experiments.	15	57.7%	2	7.7%	9	34.6%
3DL made me love science despite difficulties.	26	100%	-	-	-	-
I feel free and enjoy repeating experiments until I master learning.	24	92.3%	-	-	2	7.7%
Learning scientific shapes, symbols and equations becomes easy with 3DL.	24	92.3%	2	7.7%	-	-
I fear not to make mistakes when conducting experiments in the 3DL.	18	69.2%	2	7.7%	5	19.2%
3DL makes me feel safe and secure when dealing with laboratory materials and hazardous experiments.	23	88.5%	1	3.8%	2	7.7%
There is difficulty in transferring the results and observations of my colleagues in the 3DL.	8	32.0%	2	8.0%	15	60.0%
I trust my ability to conduct practical experiments by myself without a guide.	21	96.3%	-	-	5	19.2%
I feel I can work well using the 3DL.	26	100%	-	-	-	-
I am confident that the materials and tools that I need for experiments are available in the 3DL.	25	96.2%	-	-	1	3.8%
3DL allows individual and group work.	23	88.5%	2	7.7%	1	3.8%
What I learn through 3DL integrates with what I learn in theory sessions.	19	73.1%	2	7.7%	5	19.2%
There are clear instructions to guide my activities in the 3DL.	23	92.0%	1	4.0%	1	4.0%
I worry and fear when dealing with 3DL.	3	11.5%	1	3.8%	22	84.6%
I like to be an 3DL educational designer in the future.	24	92.3%	1	3.8%	1	3.8%
I feel bad for the length of time when conducting practical experiments and learning through 3DL.	8	30.8%	-	-	18	69.2%
I can mail from the laboratory to make any practical experiment without fear.	22	84.6%	3	11.5%	1	3.8%
3DL helps me to organize thinking and expect results more than the traditional lab does.	24	92.3%	1	3.8%	1	3.8%
3DL does not help the development of laboratory skills types.	9	34.6%	-	-	17	65.4%
It worries me to think that the information may be erased because of pressing the wrong button in the 3DL.	6	23.1%	3	11.5%	17	65.4%
I love to write practical experiment report and equations using 3DL rather than doing that in the traditional lab.	24	92.3%	-	-	2	7.7%
I like the hands-on training of basic skills required to use the laboratory tools	24	92.3%	1	3.8%	1	3.8%

* Adapted from Al Balushi (2009).

It is evident from Table (IV) that there is an agreement among the members of the sample regarding the importance of 3DL with positive attitude towards it. Further, means, standard deviations, and level of statistical significance of the average scores of the experimental and control groups posttest in the attitudinal scale towards 3DL are calculated. Table (5) shows the findings.

Table 5. Means, standard deviations, and (t) of the mean scores of the experimental and control groups posttest in the attitudinal scale towards 3DL

Group	Items	Means	SD	df	t	Sig.
Experimental	40	2.56	0.150	52	4.97	0.001*
Control		2.31	0.216			

* Significance at ($\alpha \leq 0.05$)

Table (5) shows significant differences between the mean scores of the experimental and control groups posttest in the attitudinal scale towards 3DL in favor of the experimental group. This finding emphasizes the positive attitude of the sample towards the 3DL.

3.3 Logical Thinking

To answer the research question: "What effect does the 3DL have on developing and acquiring logical thinking by the Omani fourth graders?" the logical thinking test is applied at the end of the experiment. Then, the means, standard deviations, and Multivariate analysis of variance (MANOVA) test are conducted to calculate the statistical significance of differences between both study groups; as shown in the Table (6).

Table 6. Means, standard deviations, and (F) of the mean scores of the experimental and control groups posttest in the logical thinking test.

Logical thinking skills	Group	Means	SD	df	F	Sig.
Proportional reasoning	Experimental	0.81	1.04	52	0.519	0.474
	Control	0.63	0.84			
Controlling variables	Experimental	0.89	0.97	52	4.376	0.041*
	Control	0.41	0.69			
Probabilistic inference	Experimental	1.33	1.07	52	0.082	0.776
	Control	1.26	0.81			
Correlational inference	Experimental	2.11	0.64	52	0.047	0.829
	Control	2.07	0.62			
Total	Experimental	5.19	1.33	52	3.487	0.067
	Control	4.33	1.96			

* Significance at ($\alpha \leq 0.05$) - each skill scores = 4, Total test scores = 16.

Table (6) shows no significant differences between the mean scores of experimental and control groups on the overall logical thinking skills posttest. However, it shows significant differences between the mean scores of experimental and control groups in one logical thinking skill only: controlling variables skill.

The improvement of logical thinking skills for both study groups in pre and posttest is calculated using Paired-Samples-t- Test. Findings are listed in Table (7).

Table 7. Means, standard deviations, and (t) of the mean scores of the experimental and control groups pre and posttest in the logical thinking test

Logical thinking skills		Test type	Means	SD	df	t	Sig.
Group							
Proportional reasoning	Experimental	Pre	0.67	0.88	26	0.57	0.574
		Post	0.81	1.04			
	Control	Pre	0.52	0.85	26	0.52	0.611
		Post	0.63	0.84			
Controlling variables	Experimental	Pre	0.48	0.80	26	2.51	0.019*
		Post	0.89	0.97			
	Control	Pre	0.48	0.70	26	0.40	0.611
		Post	0.41	0.69			
Probabilistic inference	Experimental	Pre	1.15	0.99	26	1.00	0.327
		Post	1.33	1.07			
	Control	Pre	1.15	0.95	26	0.44	0.663
		Post	1.26	0.81			
Correlational inference	Experimental	Pre	1.67	0.88	26	2.06	0.050*
		Post	2.11	0.64			
	Control	Pre	1.78	0.80	26	1.44	
		Post	2.07	0.62			0.161
Total	Experimental	Pre	3.96	1.81	26	4.64	0.001*
		Post	5.19	1.96			
	Control	Pre	3.93	1.41	26	1.52	0.141
		Post	4.33	1.33			

* Significance at ($\alpha \leq 0.05$)

Table (7) shows that there is an improvement in logical thinking skills for both experimental and control groups, but the degree of improvement of the experimental group students increases better than the control group students as a result of their learning using the 3DL. Statistical significant differences exist in the overall posttest and in controlling variables and correlational inference skills in favor of the experimental group. There were no statistically significant differences for proportional reasoning and probabilistic reasoning skills pre and posttest for both the experimental and the control groups.

Table (8) shows calculations used to identify the effect size of using 3DL on logical thinking skills acquisition improvement of the experimental group's students, η^2 using the equation $\eta^2 = t^2 / (t^2 + df)$, was calculated; where (t) is the value of (t) of the overall sum, and (df) is the degrees of freedom; as shown in Table (8).

Table 8. (η^2) value and the effect size of using 3DL on the logical thinking skills acquisition of the experimental group

Independent variable	Dependent variable	η^2	Effect size
Using 3DL	Logical thinking skills acquisition improvement	0.453	large

Table (8) shows that the effect size of using 3DL for the study sample is large. (45%) of the total variation of the dependent variable (logical thinking skills acquisition improvement levels) is due to the effect of the independent variable (using the 3DL). This percentage is higher than the one set by Cohen (15 percent or more), in order to consider the effect size of the independent variable on the dependent variable as large.

The growth rate of the logical thinking skills for both experimental and control groups in the pre and posttests is calculated as shown in the Table (9).

Table 9. Growth rates of the logical thinking skills of for both experimental and control groups in the pre and posttests

Logical thinking skills	Total Score	Experimental Group		Growth Rate	Control Group		Growth Rate
		Pretest M1	Posttest M2		Pretest M1	Posttest M2	
Proportional reasoning	4	0.67	0.81	3.50%	0.52	0.63	2.75%
Controlling variables	4	0.48	0.89	10.25%	0.48	0.41	1.75-%
Probabilistic inference	4	1.15	1.33	4.50%	1.15	1.26	2.75%
Correlational inference	4	1.67	2.11	11%	1.78	2.07	7.25%
Total	16	3.96	5.19	7.69%	3.93	4.33	2.50%

Table (9) shows differences between the growth rates in the means of the experimental and control groups, where the logical thinking skills growth rate of the experimental group is higher than the growth rate of the control group. In addition, controlling variables and correlational inference skills are higher in their growth rates compared to the other two skills. It is also noted the lack of growth of control variables skill of the control group.

To identify the extent to which the experimental group students respond to the logical thinking items and the ways in which they used to solve the questions, frequencies and percentages of their responses to this test are calculated as shown in the Table (10).

Table 10. Frequencies and percentages of the experimental group students to the logical thinking posttest items

Question No.	Options	The Correct Answer	Question		Reason		Reason	
			Frequencies	Percentages	Options	The correct answer	Frequencies	Percentages
First	a	c	8	33.3%	1	3	3	12.5%
	b		8	33.3%	2		13	54.2%
	c		4	16.7%	3		3	12.5%
	d		3	12.5%	4		1	4.2%
	e		1	4.2%	5		4	16.7%
Second	a	c	0	0%	1	5	4	16.7%
	b		8	33.3%	2		4	16.7%
	c		7	29.2%	3		4	16.7%
	d		7	29.2%	4		10	41.7%
	e		2	8.3%	5		2	8.3%
Third	a	c	0	0%	1	4	1	4.3%
	b		7	29.2%	2		12	52.2%
	c		6	25.0%	3		5	21.7%
	d		5	20.8%	4		4	17.4%
	e		6	25.0%	5		1	4.3%
Fourth	a	a	6	25.0%	1	4	12	52.2%
	b		6	25.0%	2		4	17.4%
	c		3	12.5%	3		3	13.0%
	d		6	25.0%	4		4	17.4%
	e		3	12.5%	5		0	0%
Fifth	a	a	12	50.0%	1		12	50.0%
	b		3	12.5%	2		4	16.7%
	c		5	20.8%	3	1	2	8.3%
	d		3	12.5%	4		4	16.7%
	e		1	4.2%	5		2	8.3%
Sixth	a	b	3	12.5%	1	2	10	43.5%
	b		6	25.0%	2		4	17.4%
	c		4	16.7%	3		5	21.7%
	d		3	12.5%	4		3	13.0%
	e		8	33.3%	5		1	4.3%
Seventh	a	a	24	100%	1	4	2	8.3%
	b		0	0%	2		15	62.5%
	c		0	0%	3		3	12.5%
	d		0	0%	4		2	8.3%
	e		0	0%	5		2	8.3%
Eighth	a	b	5	20.8%	1	5	3	12.5%
	b		19	79.2%	2		12	50.0%
	c		0	0%	3		5	20.8%
	d		0	0%	4		1	4.2%
	e		0	0%	5		3	12.5%

Table (10) shows that the percentage of those who have the correct answer for the first and second questions is weak. The highest percentage is clustered on wrong item for either the question or reason. This indicates that proportional reasoning skill among students need more training and practice to enable them from acquiring it in the best way.

3.4 Visual Thinking

To answer the research question: "What effect does the 3DL have on developing and acquiring visual thinking by the Omani fourth graders?" the visual thinking test is applied at the end of the experiment. Then, the means, standard deviations, and Independent-Samples -t-Test are conducted to calculate the statistical significance of differences between both study groups; as shown in the Table (11).

Table 11. Means, standard deviations, and (t) of the mean scores of the experimental and control groups posttest in the visual thinking test

Group	Items	Overall points	Means	SD	df	t	Sig.
Experimental	8×20	160	130.27	29.13	51	3.390	0.001*
Control			102.48	30.49			

* Significance at ($\alpha \leq 0.05$)

Table (11) shows significant differences between the mean scores of the experimental and control groups posttest in the visual thinking skills test in favor of the experimental group.

The improvement of visual thinking skills for both study groups in pre and post-test is calculated using Paired-Samples-t-Test. Findings are listed in Table (12).

Table 12. Means, standard deviations, and (t) of the mean scores of the experimental and control groups pre and posttest in the visual thinking test

Group	Test type	Means	SD	df	t	Sig.
Experimental	Pre	114.52	41.18	26	2.37	0.025*
	Post	129.67	29.99			
	Pre	100.15	27.27	26	0.48	0.638
Control	Post	102.48	30.49			

* Significance at ($\alpha \leq 0.05$)

Table (12) shows there are significant differences between the mean scores of the experimental group in the visual thinking skills in favor of the post application. It is noted that there is no statistical significant differences between the mean scores of the control group in pre and post application.

To identify the effect size of using 3DL on visual thinking skills acquisition improvement of the experimental group's students, η^2 using the equation $\eta^2 = t^2 / (t^2 + df)$, was calculated; where (t) is the value of (t) of the overall sum, and (df) is the degrees of freedom; as shown in Table (13).

Table 13. (η^2) value and the effect size of using 3DL on the visual thinking skills acquisition of the experimental group

Independent variable	Dependent variable	η^2	Effect size
Using 3DL	Visual thinking skills acquisition improvement	0.178	large

Table (13) shows that the effect size of using 3DL for the study sample is large. Eighteen percent of the total variation of the dependent variable (visual thinking skills acquisition improvement levels) is due to the effect of the independent variable (using the 3DL). This percentage is higher than the one set by Cohen (15 percent or more), in order to consider the effect size of the independent variable on the dependent variable as large.

4. Discussion

Findings show statistically significant differences in student achievement in favor of the group that studied using the 3DL with large effect size, in knowledge and metacognitive abilities levels. The above findings are partially substantiated by the reviewed literature (Al-Mutairi, 1998; Al-Anzi, 2003; Al-Qarni, 2006; Al-Shannaq et al., 2004; Al-Khalaf, 2005; Al-Radi, 2008).

Findings show that there is an agreement among the members of the sample regarding the importance of 3DL with positive attitude towards it. In addition, there are significant differences between the mean scores of the experimental and control groups posttest in the attitudinal scale towards 3DL in favor of the experimental group. The above findings are corroborated in the literature (Al-Shaiey, 2006; Shabbat, 2005; Al-Balushi, 2009).

There is an improvement in logical thinking skills for both experimental and control groups, but the degree of improvement of the experimental group students increases better than the control group students as a result of their learning using the 3DL. Findings also show statistical differences between the growth rates in the means of the experimental and control groups, where the logical thinking skills growth rate of the experimental group is higher than the growth rate of the control group. The works of Redha (2010) and Ahmad (2010) confirm the above findings.

Findings also show significant differences between the mean scores of the experimental and control groups posttest in the visual thinking skills test in favor of the experimental group with large effect size of using 3DL for the study sample. Redha (2010) and Ahmad (2010) substantiate the above findings.

4.1 Conclusions and Recommendations

We conduct this study to measure the effectiveness of the 3DL on Omani students' acquisition of practical abilities and skills. Using four research tools in a Pre-Post Test Control Group Design, findings show statistically significant differences in student achievement in favor of the experimental group. The results show students' attitudes are positive towards using 3DL in teaching. Improvements in logical and visual thinking are also observed. The authors recommend that 3DL to be used in Omani schools and emphasize the need to conduct more research on different types of virtual labs in science education at higher education institutions.

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