The Effect of Using Virtual Laboratories in Developing Creative Thinking in the Science Course of Elementary Third Graders in Al-Taif

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Abstract

This research aimed to identify the effect of using virtual laboratories in developing cognitive achievement and creative thinking in the Science Course of the elementary third graders in Al-Taif. To meet these aims, the semi-experimental research was used to study the relationship between the research variables. The research sample consisted of 60 pupils, divided into two groups, the control group (N=30), who used the regular laboratory in the school, and the other experimental group (N=30), who studied using the virtual lab. To collect data, the research utilized a cognitive achievement test and a creative thinking scale. Among the most important results that there were statistical differences between the mean scores of the control and experimental groups in the overall degree of cognitive achievement levels and creative thinking skills in favour of the experimental group pupils. The research recommended that building virtual science laboratories that operate permanently alongside school laboratories would contribute to the development of cognitive achievement and creative thinking skills of the elementary third graders.

Keywords: *Virtual laboratories, Creative thinking, Elementary Third Graders, Al-Taif.*

أثر استخدام المعامل الافتراضية في تنمية التفكير الإبداعي بمقرر العلوم للصف الثالث الابتدائي بمدينة الطائف

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المستخلص:

هدف البحث الحالي إلى التعرف على أثر استخدام المعامل الافتراضية في تنمية التحصيل المعرفي والتفكير الإبداعي بمقرر العلوم للصف الثالث الابتدائي بمدينة الطائف، ولتحقيق ذلك استخدم المنهج شبه التجريبي لدراسة العلاقة بين متغيرات البحث، وتكونت عينة البحث في (٦٠) تلميذاً، تم تقسيمهم إلى مجموعتين إحداهما ضابطة وعددها (٣٠) وتدرس باستخدام المعمل التقليدي في المدرسة، والأخرى تجريبية وعددها (٣٠) تدرس باستخدام المعمل الافتراضي، وتمثلت أدوات البحث في اختبار التحصيل المعرفي ومقياس التفكير الإبداعي، وتوصل البحث لعدة نتائج أهمها وجود فروق بين متوسطات درجات أفراد عينة البحث بالمجموعتين الضابطة والتجريبية في الدرجة الكلية لمستويات التحصيل المعرفي ومهارات التفكير الإبداعي، وذلك لصالح المجموعة التجريبية، وأوصى البحث العمل على بناء معامل افتراضية للعلوم تعمل بشكل دائم بجانب المعامل المدرسية تسهم في تنمية التحصيل المعرفي ومهارات التفكير الإبداعي لدى تلاميذ المرحلة الثالث بالتعليم الابتدائي.

الكلمات المفتاحية: المعامل الافتراضية، التفكير الابداعي، طلاب الصف الثالث الابتدائي.

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Introduction

Nation's progress and prosperity depend on the level of education and learning among its members, their awareness of the importance of learning, and acquiring basic skills that support them in their life. This can be done using the latest technologies that seek to achieve such goals; Creative thinking constitutes a major goal of scientific education and, in turn, of the natural sciences for all educational levels, especially the basic stage of education. Therefore, paying attention to these skills is necessary amid the challenges facing our societies.

In fact, creative thinking mainly focuses on training people to invent new thinking patterns by organizing their scientific knowledge, increasing their awareness of their abilities, gaining self-confidence, and overcoming life's problems in the future. Therefore, the development of creative thinking among learners is one of the most important educational goals at all levels and in all subjects (Demir & Isleyen, 2015, p. 51; James, 2015, p. 1032)[1]. Therefore, interest in creative thinking has increased significantly since creativity was established as one of the components of modern societies. It also becomes a necessity to adapt to the existing global changes, the knowledge-based economy, and one of the components for preparing graduates qualified for global competition, and who are creative in their lives and future jobs (Cardoso et al., 2015, p. 864; Cocu, et al., 2015, p. 173).

Hence, the ability of the educational system to develop creative thinking among learners is seen as one of the basic criteria for judging the success of this system. In addition to that, the four important pillars of creativity "the 4P Creativity Quadrant", proposed by Rhodes (1961). This quadrant outlines the features of creativity and is centred on creativity. around it its various definitions. According to him, creativity begins with a "Person", he uses the creative "Process"; to access a creative “Product”, in a “Press” environment that supports creativity (Kanematsu & Barry, 2016, p. 9; Cropley, 2016, pp.159-166).

[1] References are formatted according to APA Style, 7th Edition.

Researchers agree that developing learners' scientific thinking skills in general and creative thinking, in particular, is one of the important goals of science education and scientific education at all educational levels (such as: Qahm, 2021; Al Deakin, 2015; Ramadhan &Irwanto, 2017; Trisnaningsih, Parno, & Setiawan, 2021).

There are many creative thinking skills, which appear through educators' approach to the concept of creative thinking. Guilford (1967) sees that creative thinking depends on originality, flexibility, fluency, and a context of problems. He defined "Creativity as a method of directed and purposeful thinking, through which the individual seeks to discover relationships, new methods or new solutions to his problems, or he invents new methods, devices or produces beautiful artistic pictures that he makes use of". Usta&Akkanat (2015, p. 1409) defined creative thinking as "Relying on previous knowledge and experiences, sensitivity to problems and their solutions, and understanding the nature of science, to develop new, distinct, extraordinary and useful knowledge, experiments, theories, and scientific products".

Accordingly, the creative thinking skills of learners become clear in "originality, flexibility, fluency and sensitivity to problems" as an entry point for solving educational and life problems; Torrance (1993) identified the components of creative thinking skills as : Fluency: the ability of the individual to recall the largest amount of appropriate ideas in a specific period of time for a problem or exciting situation; Authenticity: The ability of an individual to give an idea that is new and out of the ordinary, or contrary to what is common; Flexibility: The ability of the individual to produce appropriate solutions or forms, these solutions are characterized by diversity and atypical, as it is the ability to change the situation in order to generate new and diverse solutions to stimuli or problems; and Sensitivity to problems: The individual's ability to recognize weaknesses in an exciting situation or problem, and at a specific time, to reach the causes of problems in that situation, and to find solutions to them.

Therefore, educators highlight that developing students' creative thinking skills has become an urgent necessity, as it is a basic goal of modern education, and a major tool for facing life problems and future challenges. The educational literature indicates that the learner-cantered science teaching environment that allows freedom and openness is - in general - a supportive environment of creative thinking skills (Daud, Omar, Turiman & Osman, 2012, 472).

Furthermore, it also helps pay the attention to the social context of learning, encourage social interaction and cooperation, knowledge sharing, expression, and diversity of opinions, (Cocu et al., 2015, 174 -175), practice independent exploratory research activities and science processes, encourage learners to access new examples, describe and interpret scientific concepts and theories included in educational content, and give learners the opportunity to apply scientific knowledge in new situations (Akcay, 2013, 49).

Despite the importance of the practical aspect in the educational process, there are obstacles that prevent the establishment of scientific laboratories in most educational institutions. This problem can be solved by adopting virtual reality technology, which allows building virtual laboratories, that can simulate what happens in real laboratories. In addition, supporting virtual laboratories with aspects of communication and interaction with others as an educational environment should meet the actual needs of the learner through modern technological media as the learner has the ability to learn through the programs provided to him. In these labs, the teacher acts as a mentor and guide, and this is done in educational institutions or at home. Moreover, virtual education programs are characterized by interaction between the learner and the educational material. The direct interaction between the teacher and the learner is overcome through social media conversations, the learner's progress is monitored, as well as there is an opportunity to improve his level.

Virtual labs are one of the most important virtual learning environments that provide the learner with feedback on their lab performance at the speed and quality he wants. Virtual labs make the practical aspects more fun and exciting, and reducing the learning time that the student spends in the traditional lab, where experiments are difficult to conduct due to its danger or material cost. In addition, programs of virtual laboratories have tools that help support experiment such as graphs, animations, and analysis. Virtual laboratories also help eliminate the problem of insufficient laboratory equipment, especially valuable or unavailable ones (Al-Ghamdi, 2016; Qahem, 2021).

The virtual laboratory environment relied on the social constructivist theory as a philosophical basis and made the learner an interactive main focus in the learning process. Brown referred to the need to shift from cognitive learning to situational learning, and he means: the shift from giving information to situational training. As such, the view of educational goals has changed from being predetermined, to looking at them as expectations that determine the direction of the learner’s progress, looking at educational tasks as one of the multiple learning activities that the learner may choose by himself, shifting from problem solving to dealing with evidence and proofs, and shifting from effectiveness to proof. The design of these labs that is based on the science of knowledge focuses on quantitative criteria, such as effectiveness and efficiency more than quantitative criteria for quality and understanding, and the learner is at its centre (Khamis, 2003, 44-45).

In this respect, Cronins (1997) classified educational virtual laboratories into three types as follows:

1. Non-impressive Virtual Labs, also called "Desktop VL", which is the most widespread and least expensive. It is a three-dimensional stereoscopic computer virtual world that you can roam freely through. One of its shortcomings is the lack of sense for the part of the learner by merging with the virtual world that he sees.
2. Semi Immersive Virtual Labs, also called Projected VL, that enable a number of participants to gather in a virtual room on a large screen that expands up to 130 degrees; It allows the largest possible field of vision, which gives them a relative sense of merging with the virtual world that they see in front of them on the screen. Its shortcoming is that the viewer of the display is aware of the presence of others and does not allow individual interaction with the virtual laboratory environment.
3. Fully Immersive Virtual Labs that allow a great deal of capturing the learner's imagination. It consists of a visual display unit placed on the learner's head, so he is completely isolated from the outside world, and surrounded by virtual reality, which gives him a strong sense of living in the virtual laboratory environment, and his abilities vary according to the clarity of vision, the rate of modernity, and the age of the images used in the presentation. Its main shortcomings are the presence of various mechanical problems and weak animation on the screen.

Literature and previous research revealed that the most important advantages of virtual laboratories, as indicated by Tatli&Ayas (2013), are summarized as follows:

- Compensating the lack of real laboratory capabilities, due to the lack of sufficient funding.
- Challenging risk factor for the experiments that are difficult to perform in real laboratories.
- The possibility of visual display of data and phenomena, which cannot be shown through real experiments.
- The possibility of covering all course ideas with practical, interactive experiments and activities.
- Synchronization between the process of explaining theoretical ideas and practical application at the same time.
- Making laboratory experiments and activities available to learners at anytime and anywhere.
- Giving prominence to the principle of individuality in learning by conducting experiments more than once according to students' abilities and the appropriate time for them.
- The possibility of documenting the results electronically with the aim of analysing, processing, and sharing them with colleagues.
- The possibility of evaluating student performance electronically and following up their progress in conducting activities and experiments.
- Partnership in building and developing virtual laboratories by supporting the educational process and reducing its high costs.

Therefore, virtual labs represent a basic pillar in science teaching to develop learners' understanding of scientific concepts and facts in more attractive and interesting ways for the learner and develop various scientific thinking skills. This is confirmed by many educational studies on the importance of employing virtual labs in teaching science ideally, including: The study of Andres (2009), which indicated that virtual laboratory environments are an educational tool that helps learners to learn science in a more effective way, through their interaction with those environments by controlling the learning process. The study of Ramadan and Irwanto (2017) that revealed the impact of using Virtual labs in enhancing students' thinking abilities, skills and scientific attitudes, and a study whose results indicated the effective impact of developing a STEM approach based on a virtual lab. Equipped reactions to improve critical thinking skills in the concept of acid base.

At the level of the Kingdom of Saudi Arabia, the study of Al-Baltan and Al-Raqi (2011) indicated that based on the importance of this technology in the teaching and learning process, the Kingdom, through the King Abdullah project - may God have mercy on him - represented by the Ministry of Education, has given great attention to providing computers and virtual simulation programs For practical experiments in schools, most notably the Crocodile lips program, a famous British program that was approved by the Ministry and Arabized by companies specialized in computer systems, and is one of the best virtual simulation programs in science experiments.

Despite acknowledging the significance of virtual laboratories, certain studies have revealed the existence of obstacles concerning their application across all levels of science and chemistry education. These challenges primarily revolve around the neglect of individual differences between experiments and educational activities, as well as the lack of realism in depicting materials and resulting gases, as highlighted by Al-Juhani (2013). Consequently, to optimize the potential of virtual laboratories in fostering creative thinking skills in diverse science courses, a more tailored and specialized approach to their development is imperative.

Statement of the problem

Based on the goals of scientific education, developing students creative thinking skills “fluency, originality, flexibility and sensitivity to problems” , as one of the objectives of science education, help them deepen their understanding in a procedural manner, contributes to meeting basic needs in solving current and future problems, and enable them to interact and exchange experiences in a social environment. Although the study of science represents a fertile field for the development of creative thinking among learners (Al-Zahrani, 2015, 399; Akcay, 2013, 49), due to its connection with the environment, and the nature of the topics and problems it contains that can be used in its development (Al-Wasimi, 2013), teaching science using activities and experiments in the traditional way does not guarantee the development of creative thinking skills, nor does it clearly define the mechanisms of their development in science classes, and how to integrate them into the educational content of science (Meyer & Lederman, 2013).

Due to the current conditions of the spread of epidemics; avoiding the obstacles of relying on labs in their traditional form and their multiple risks to learners in the basic education stage; the lack of real laboratory capabilities; the risk factor; the coverage of all the ideas of the course; the synchronization between the process of explaining theoretical ideas and practical application; availability in any time and place; taking into account the principle of individualization in learning, the possibility of evaluating student performance electronically (Tatli&Ayas, 2013); and In light of the technological progress, Brown referred to the need to shift from cognitive learning to hypothetical situational. Therefore, Wang (2008, 11) stressed the need to use the virtual lab via the Internet in the educational process, because it will be the key to improving the efficiency of distance education, and because experiments are an essential element in science courses as an applied image linking knowledge and application. Through the virtual lab, learners have the freedom to conduct experiments at any time and place.

Therefore, there is a need for the current research to build a virtual laboratory dedicated to the experiments and activities of third grade sciences and measure its effectiveness in developing creative thinking skills in the science course among the elementary third graders in Al-Taif, Saudi Arabia.

Questions of the Research:

The current research attempted to answer the following questions:

1. What is the effect of using virtual laboratories in developing cognitive achievement in the science course of elementary third graders in Al-Taif, Saudi Arabia?
2. What is the effect of using virtual laboratories in developing creative thinking in the science course of elementary third graders in Al-Taif, Saudi Arabia?

Hypotheses of the Study: The current research tested the following hypotheses:

1. There is a statistically significant difference at $\alpha \leq 0.05$ between the mean scores attained by the control group and those of the experimental group in the post test of the cognitive achievement in favour of the experimental group pupils.

2. There is a statistically significant difference at $\alpha \leq 0.05$ between the mean scores attained by the control group and those of the experimental group in the post test of the creative thinking skills in favour of the experimental group pupils.

Aims of the Research: This research sought to achieve the following **aims**:

- Exploring the effect of using virtual laboratories in developing cognitive achievement in the science course of elementary third graders in Al-Taif, Saudi Arabia.
- Studying the effect of using virtual laboratories in developing creative thinking in the science course of elementary third graders in Al-Taif, Saudi Arabia.

Significance of the Research The results of this research might benefit the following:

- Curriculum designers: By utilizing the virtual labs that may benefit in reorganizing the science content, which leads to the development of cognitive achievement and some creative thinking skills of Elementary school students.
- Researchers: By providing a model for virtual laboratories that can be tested on other research variables, they can also benefit from the cognitive achievement test and the creative skills scale in preparing tests and scales that measure different thinking skills.
- Teachers: By practicing the procedural steps in the teacher's guide for using virtual laboratories, and the way to use them in developing cognitive achievement and some creative thinking skills for students as shown in the teacher's guide, in addition to informing them with how to measure research variables in a functional manner.
- Pupils: By developing their cognitive achievement and some of their creative thinking skills, after practicing the activities that they carry out in virtual laboratories.

Delimitations of the study: The results of the research are delimited to the following:

- Creative thinking skills "fluency, originality, flexibility, sensitivity to problems", which are critical components of creative thinking. Limiting the investigation to these skills allows for a more focused and in-depth analysis of their impact on students' performance within the virtual labs' context.
- The "Matter" unit in the science book of the elementary third graders in the second semester of the year 2021/2022 AD. The research narrows its scope to a particular subject area. This approach ensures a concentrated examination of the effects of virtual labs on creative thinking skills specifically related to the "Matter" unit.
- The cognitive achievement will be delimited to three dimensions, i.e., remembering, understanding, applying; to focus the research on specific aspects of cognitive learning outcomes. Each dimension represents a different level of cognitive processing, which allows for a more nuanced analysis of students' performance in the study.
- A group of elementary third graders at Al-Taif, Saudi Arabia so the researcher can better control variables that may arise from cultural, geographical, or institutional differences. This delimitation allows for a more homogenous sample, making it easier to draw meaningful conclusions about the impact of virtual labs on creative thinking skills in this specific context.

Definition of terms:

Virtual labs in science:

The researcher operationally defines virtual labs as: One of the e-learning applications that relies on simulating the real lab, using pre-prepared software. These virtual labs utilize pre-prepared software to enable teachers and students in the third grade of elementary school to practice science experiments and activities related to the "Matter" unit. These activities can be conducted over the Internet either synchronously or asynchronously.

Critical thinking in science:

The ability of third-grade students to find new ideas and solutions, through their study of the unit (Matter) in the science book using a virtual lab by producing the largest number of responses in a certain period of time (fluency), with the diversity of those ideas and solutions (flexibility), innovation in them by finding rare, unfamiliar ideas (originality), and realizing the causes of problems in that situation (problem sensitivity).

Previous studies and research related to research variables:

By reviewing previous studies and research, it was found that the majority of studies looking at the effect or effectiveness of virtual laboratories in developing cognitive achievement and thinking skills, in general, used ready-made laboratories that are used with chemistry, physics and science in general, and neglected the different natures of sciences from each other and the characteristics of each stage of study. These studies were concerned with cognitive achievement, practical skills, and survey in general, and neglected the creative thinking skills, which are the impetus for innovation from fluency, originality, flexibility and sensitivity to solving problems. In addition, it was found a scarcity of research of basic education, especially the third grade of elementary school. The following is a brief presentation of some previous research.

- The study of Qahm (2021) aimed at revealing the impact of virtual laboratories on developing scientific inquiry skills among female students of the fifth elementary grade in Jeddah. The study used the one-group quasi-experimental approach. The study sample consisted of (35) female students who were chosen by the intentional sampling method. The study tools consisted of a performance test and an observation sheet. The study results revealed that there was a statistically significant difference between the mean scores of the experimental group students who use virtual laboratories, in the pre and post application of the performance test and its observation sheet for scientific inquiry skills in favour of the posttest. The study recommended employing virtual laboratories in teaching science and its branches.
- The study of Hazaa and Qutb (2020) aimed to identify the effectiveness of using virtual laboratories in the academic achievement of secondary school students in a chemistry course in Jeddah, Saudi Arabia. The study used the

quasi-experimental approach. The study sample consisted of (50) students who were randomly divided into two groups: an experimental group (N=25) who studied in virtual laboratories, and a control group (N=25) who studied in traditional laboratories. The study tools included only an achievement test. The results of the study revealed that there were statistically significant differences between the mean scores of the experimental and control group students in the post test of the achievement test in the chemistry course in favour of the experimental group.

- The study of Al-Dakin (2015) aimed to explore the effect of using virtual laboratories in developing academic achievement and critical thinking skills in the chemistry course at the secondary stage in Riyadh. The study used the quasi-experimental research. The study sample consisted of (80) students, who were divided into two groups, one of them is experimental (N=40) who used the virtual lab (PHET), and the other is the control group (N=40) who used the traditional lab. The study tools were the achievement test and the Watson and Glaser critical thinking test codified on the Saudi environment, in addition to the teacher and student's guide to using the virtual lab PHET. The results concluded that there were differences between the mean scores of the study participants in the experimental and control groups in the total degree of academic achievement and the development of critical thinking skills, in favour of the experimental group students.
- The study of Tatli&Ayas (2011) aimed to identify the effect of the virtual chemistry lab on students' achievement (VCL). The study used the quasi-experimental approach. The study sample consisted of (90) ninth-grade students, who were randomly divided into an experimental group that studied using the virtual chemistry lab and the other control ones studied in the traditional lab. The study tools were the scientific knowledge test and the scientific skills observation card. The results revealed that students of the experimental sample outperformed in acquiring scientific knowledge and skills, and laboratory equipment knowledge, and the growth of skills among students was noted, which indicates the importance of using the virtual lab in teaching science.
- The study of Kun Yun and Jia Cheng (Yang & Heh (2007) aimed at revealing the effect of using virtual laboratories supported by traditional laboratories on the development of academic achievement, scientific skills, and attitude towards computers among tenth graders. The study used the quasi-

experimental approach. The study sample consisted of (150) students at the High School in Taiwan, who were divided into two groups, an experimental group using the electronic lab supported by the traditional lab, (N=75), and a control group using the traditional lab (N=75). The study tools were an achievement test, an observation sheet, and an attitude inventory. The study concluded that there were statistically significant differences between the mean scores of the experimental and control group students in the post application of the achievement test and the observation card in favour of the post application. It recommended the need to move towards the use of electronic reality technologies, especially virtual laboratories in the educational process.

Research method and procedures: The research procedures included:

1- Research method

The quasi-experimental approach was used, which is consistent with the nature of the current study, in order to study the effectiveness of using virtual laboratories in developing creative thinking in the science course for third-grade pupils in Al-Taif (the study sample).

2- Developing the experimental material (a teacher's guide to using virtual laboratories in developing creative thinking).

A guide has been prepared for the teacher to use virtual laboratories in developing creative thinking in the science course for the third grade of elementary school, and it includes the following:

- Introduction: It includes a description of the guide and the main components of the virtual labs.
- Guidelines and instructions for the teacher: It demonstrates creative thinking skills in science.
- General and procedural objectives for teaching the "Matter" unit in the science course of the third elementary school.
- The main and sub concepts of the unit "Matter" in the science course of the third elementary school.
- The scientific and practical activities of the unit "Matter" in the science course of the third elementary school.

- Time plan for teaching unit topics: As 8 sessions were set for a period of four weeks.
- Formulating the unit's content in the form of (8) lessons according to the teaching using virtual labs; so that each lesson has its procedural objectives, teaching aids, lesson plan, and evaluation methods.

The teacher's guide was presented to a group of specialists, to verify its validity, and the necessary modifications were made in the light of their observations. Accordingly, a virtual learning environment (virtual lab) was developed to implement scientific and practical activities in the unit of Matter, and it was uploaded on the Internet to be available at any time and place. The activities and experiments of the virtual science lab were submitted to the jury members, and the necessary adjustments were made in the light of their observations, and thus the manual and the virtual lab became ready as a processing tool for teaching science to third grade students.

3- Research tools:

According to the current research variables, two tools were developed: one for assessing the cognitive achievement and the second for assessing some creative thinking skills.

a) The cognitive achievement test:

The cognitive achievement test, in its initial form, consisted of six dimensions: (Remembering - Understanding - Applying) with a total of (14) questions, and the psychometric properties were calculated as follows:

- **Trustees' validity**The initial version of the test was submitted to a group of experts and specialists in education and psychology, and they were asked to express their opinions on: (The extent of the question's validity to measure the dimension - the extent of the scientific accuracy of the question), with the possibility of deleting, modifying or adding to the test items. In light of their responses, question (7) that belongs to the understanding dimension, and the two questions (13, 14) were deleted for repetition with (6, 11). The final test consisted of (12) questions, and the following table provided a detailed presentation of the distribution of test questions:

Table 1
Specifications of the cognitive achievement test:

	Lessons	Question No. Remember	Understand	Apply	Total	Percentage
1	Matter and its measurement	1	5	9	3	33,3%
2	Matter conditions	2	6	10	3	33,3%
3	Physical changes	3	7	11	3	33,3%
4	Chemical changes	4	8	12	3	33,3%
	Total	4	4	4	12	100%
	Percentage	33,3%	33,3%	33,3%	100%	

Scoring the cognitive achievement test:

One score for the multiple-choice question is given in case of the correct answer.

The cognitive achievement test was applied to the pilot sample for the purpose of calculating the following:

- **Internal consistency:** To ensure the internal consistency of the test, correlation coefficients were found between the score of each question and the total score for the test, and between the total score for the main dimension and the total score for the test.

Table 2
Correlation coefficients between the score of each question, the total score of the dimension to which it belongs, and the total score of the test

Remember		Understand		Apply	
No.	Correlation coefficient	No.	Correlation coefficient	No.	Correlation coefficient
1	0.663**	5	0.696**	9	0.660**
2	0.623**	6	0.477**	10	0.614**
3	0.534**	7	0.739**	11	0.756**
4	0.756**	8	0.653**	12	0.696**
Dimension	0.913**	Dimension	0.897**	Dimension	0.910**

From the previous table, it is clear that there is a statistically significant correlation coefficients at the level of 0.01, between the 12 questions of the cognitive achievement test and the total score of the test.

The correlation coefficients between the total score of the three dimensions and the total score of the test were also calculated, as shown in the following table:

Table 3
Correlation coefficients between the total score of the six dimensions and the total score of the test

Dimension	Remember	Understand	Apply	Test
Remember	____			
Understand	**0.731****	____		
Apply	**0.757****	**0.710****	____	
Test	**0.913****	**0.897****	**0.910****	____

In light of the results shown in the previous table, it became clear that they were all significant at the level of 0.01; which shows the validity of the internal consistency of the test.

- **Reliability of the test:** Reliability of the test was calculated by the half-split method. The value of the reliability coefficient of Spearman and Gettman for the test were (0.918, 0.917, 0.707) respectively, and for the dimensions were (Spearman 0.687, 0.759, .706), and (Gottman 0.685, 0.755), respectively. This indicates the stability of the test scores if it is applied to the same sample under the same conditions.

The average time for applying the cognitive achievement test to the pilot sample took (30) minutes, so the test in its final form consisted of (12) questions (See appendix 1) in its final form.

b) Creative thinking skills scale:

The creative thinking skills scale, in its initial form, consisted of four dimensions: (Fluency - Flexibility - Originality - Sensitivity to problems) with a total of (16) questions, and the following table provided a detailed presentation of the distribution of the scale questions:

Table 4

Table of specifications of the scale of creative thinking skills found in the third grade elementary science unit "Matter":

	Lessons	Questions				Total	Percentage
		Fluency	**Flexibility**	**Originality**	**Sensitivity to problems**		
1	**Matter and its measurement**	**1**	**5**	**9**	**13**	**4**	**25%**
2	**Matter conditions**	**2**	**6**	**10**	**14**	**4**	**25%**
3	**Physical changes**	**3**	**7**	**11**	**15**	**4**	**25%**
4	**Chemical changes**	**4**	**8**	**12**	**16**	**4**	**25%**
	Total	**4**	**4**	**4**	**4**	**16**	**100%**
	Percentage	**25%**	**25%**	**25%**	**25%**	**100%**	

The creative thinking skills scale included the following skills in its procedural form:

- **Fluency:** The ability to produce the largest possible number of ideas that can be recalled, or the speed with which these ideas are recalled, their flow and ease of generation, including the quantitative aspect, and are done according to specific conditions and in a specific time.
- **Flexibility:** The ability to change the state of mind by changing the situation, which means the ability to diversify ideas in a unique way and at a specific time, as the degree of flexibility increases with the increase in qualitative ideas.
- **Originality:** Perceiving things in a new and unfamiliar image, or produce an idea, relationship or scientific significance that is not repeated and unique in a specific time.
- **Sensitivity to problems:** The ability to recognize weaknesses or shortcomings in an exciting situation at a specific time, in order to understand the causes of problems in that situation.

- **Scoring the creative thinking skills scale:** The scale includes four skills of creative thinking that are limited to 5 minutes for each response, so the scale time is (80) minutes. The score that the student gets is estimated by the number of answers the students reach in the question, and the student's score on each question is estimated at five marks if five responses are put, and the total score on the test is (80) degrees.

The psychometric properties were calculated as follows:

- **Trustees' validity:** The initial version of the scale was submitted to a group of experts and specialists in education and psychology, and they were asked to express their opinions on: (The extent of the question's validity to measure the intended skills - the extent of the scientific accuracy of the question, with the possibility of deleting, modifying or adding to the items of the scale). In light of the jury members' responses, the scale was ready to be applied to the pilot sample.
- **Internal consistency:** To ensure the internal consistency of the scale, correlation coefficients were found between the score of each question and the total score for the scale, and between the total score for the main dimension and the total score for the scale.

Table 5

Correlation coefficients between the score of each question, the total score of the dimension to which it belongs, and the total score of the scale

Fluency		Flexibility		Originality		Sensitivity to problems	
No.	**Correlation coefficient**	**No.**	**Correlation coefficient**	No.	**Correlation coefficient**		**Correlation coefficient**
1	**0.857****	**5**	**0.534****	**9**	**0.649****	**13**	**0.755****
2	**0.467****	**6**	**0.717****	**10**	**0.707****	**14**	**0.648****
3	**0.505****	**7**	**0.794****	**11**	**0.699****	**15**	**0.636****
4	**0.681**	**8**	**0.803****	**12**	**0.658****	**16**	**0.776****
Skills	**0.824**	**Skills**	**0.838****	**Skills**	**0.813****	**Skills**	**0.876****

From the previous table, it is clear that there is a statistically significant correlation coefficients at the level of 0.01, between the 16 questions of the scale and the total score.

The correlation coefficients between the total score of the four dimensions and the total score of the scale were also calculated, as shown in the following table:

Table 6

Correlation coefficients between the total score of the main skills and the total score of the scale

Skills	Fluency	Flexibility	Originality	Sensitivity to problems	The scale
Fluency	____				
Flexibility	0.607**	____			
Originality	0.598**	0.488**	____		
Sensitivity to problems	0.561**	0.701**	0.656**	____	
The scale	0.824**	0.838**	0.813**	0.876**	____

In light of the results shown in the previous table, it became clear that they were all significant at the level of 0.01; which shows the validity of the internal consistency of the scale.

- **Reliability of the scale:**

Reliability of the scale was calculated using Cronbach's alpha method. The value of the reliability coefficient was (0.916) for the whole scale, and its dimensions fluency, flexibility, originality, sensitivity to problems were (0.715, 0.838, 0.845, 0.814), respectively. This indicates the reliability of the scale degrees if it is applied to the same sample in the same conditions.

The average time for applying the scale to the pilot sample took (60) minutes, so the scale in its final form consisted of (16) questions (See appendix 2) in its final form.

Preparation of the experiment:

Selection of the research participants:

The nature of the current research required the selection of two groups, one control and the other experimental, from third-grade pupils in the elementary education stage in the city of Al-Taif, Saudi Arabia, in the second semester of the academic year (2021/2022) utilizing the odd and even numbers of the school lists.

To ensure the homogeneity of the research groups, the cognitive achievement test and the creative thinking skills scale were administered before the experiment. The differences were calculated between the scores of both groups and the results are illustrated in the following table:

- **Homogeneity of the research groups in the achievement test**

To test the homogeneity of the research groups in the achievement test of science, the value of the t-test was calculated for the differences between the mean scores of the two research groups in the pretest of test as shown in the following table:

Table 7
Means, standard deviations, "t" value of the differences between the mean scores of the two research groups in the pretest of the cognitive achievement (N = 60)

Dimensions	Groups	Total Score	Mean	SD	SD Error	F	t	Sig.
Remember	Control	4	1.07	0.740	0.135	58	0.177	0.860
	Experimental		1.03	0.718	0.131			
Understand	Control	4	0.83	0.531	0.097		0.424	0.673
	Experimental		0.77	0.679	0.124			
Apply	Control	4	0.70	0.651	0.119		0.608	0.545
	Experimental		0.60	0.621	0.113			
Total score of the test	Control	12	2.60	1.221	0.223		0.666	0.508
	Experimental		2.40	1.102	0.201			

To avoid the error of the first type, the researcher modified the significance level using Bonferroni Adjustment, where the significance level (0.05) was divided by the number of dimensions (3) to become the new significance level (0.017). By looking at the values of (t) in the previous table, it was found that it is (0.666).) which is not statistically significant at the level ($\alpha \geq 0.05$) for each dimension of cognitive achievement separately, and the total test. Accordingly, it was verified that there is parity between the two research groups in cognitive achievement in science.

- **Homogeneity of the research groups in the creative thinking skills scale in science:**

To test the homogeneity of the research groups in the creative thinking skills scale in science, the value of the t-test was calculated for the differences between the mean scores of the two research groups in the pretest of test as shown in the following table:

Table 8
Means, standard deviations, "t" value of the differences between the mean scores of the two research groups in the pretest of the creative thinking skills (N = 60)

Skills	Groups	Total Score	Mean	SD	SD Error	F	t	Sig.
Fluency	**Control**	**20**	**3.87**	**1.074**	**0.196**	**58**	**0.459**	**0.648**
	Experimental		**3.73**	**1.172**	**0.214**			
Flexibility	**Control**	**20**	**3.77**	**1.278**	**0.233**		**0.535**	**0.595**
	Experimental		**3.60**	**1.133**	**0.207**			
Originality	**Control**	**20**	**3.60**	**1.354**	**0.247**		**0.567**	**0.573**
	Experimental		**3.40**	**1.380**	**0.252**			
Sensitivity to problems	**Control**	**20**	**3.57**	**1.357**	**0.248**		**0.182**	**0.856**
	Experimental		**3.63**	**1.474**	**0.269**			
Total score of the scale	**Control**	**80**	**14.80**	**2.644**	**0.483**		**0.678**	**0.501**
	Experimental		**14.37**	**2.297**	**0.419**			

To avoid the error of the first type, the researcher modified the significance level using Bonferroni Adjustment, where the significance level (0.05) was divided by the number of dimensions (3) to become the new significance level (0.013). By looking at the values of (t) in the previous table, it was found that it is (0.666).) which is not statistically significant at the level (α ≥ 0.05) for each skill of creative thinking separately, and the total scale. Accordingly, it was verified that there is parity between the two research groups in creative thinking skills in science.

Results of the study

This part deals with the results of the statistical analysis, and discusses and interprets the results, as follows:

1- Results related to the effect of virtual labs on developing cognitive achievement

To answer the first research question, which states: "What is the effect of using virtual labs on developing cognitive achievement in the science course for the third elementary graders in Al-Taif, Saudi Arabia?", and verifying the hypothesis associated with it, which states "there is a statistically significant difference at the level (α≤0.05). between the mean scores attained by the control group and those of the experimental group in the posttest of the cognitive achievement in favour of the experimental group pupils", the value of the t-test for the differences between the mean scores of the two research groups in the posttest of the cognitive achievement was calculated as shown in the following table:

Table 9

Means, standard deviations, "t" value of the differences between the mean scores of the two research groups in the posttest of the cognitive achievement (N = 60)

Dimensions	Groups	Total Score	Mean	SD	SD Error	F	t	Sig.	Effect Size (η^2)
Remember	Control	4	2.63	0.669	0.122	58	9.439	0,05	0.606
	Experimental		3.90	0.305	0.056				Mean
Understand	Control	4	2.50	0.630	0.115		9.497		0.609
	Experimental		3.80	0.407	0.074				Mean
Apply	Control	4	2.47	0.681	0.124		8.497		0.555
	Experimental		3.73	.450	0.082				Mean
Total score of the test	Control	4	7.60	1.276	0.233		14.071		0.773
	Experimental		11.43	0.770	0.141				Large

To avoid the error of the first type, the researcher modified the significance level using Bonferroni Adjustment, where the significance level (0.05) was divided by the number of dimensions (3) to become the new significance level (0.017).

The results shown above reveal that there are statistically significance differences at 0.017 in favour of the experimental group pupils for each dimension in the test as well as the whole test. Hence, the first hypothesis was accepted.

With regard to the values of the effect size caused by the independent variable in the development of cognitive achievement, the values were high for the dimensions of cognitive achievement (remembering - understanding - application - total test), respectively; This means that (61%) of the variance occurring with the skill of remembering, (61%) of the variance occurring in the dimension of understanding, (56%) of the variance occurring in the dimension of application, and (77%) of the variance occurring in the level of cognitive achievement, are due to the independent variable (the virtual labs). The following figure shows the size of the differences between the mean scores of the participants in the posttest of the cognitive achievement test.

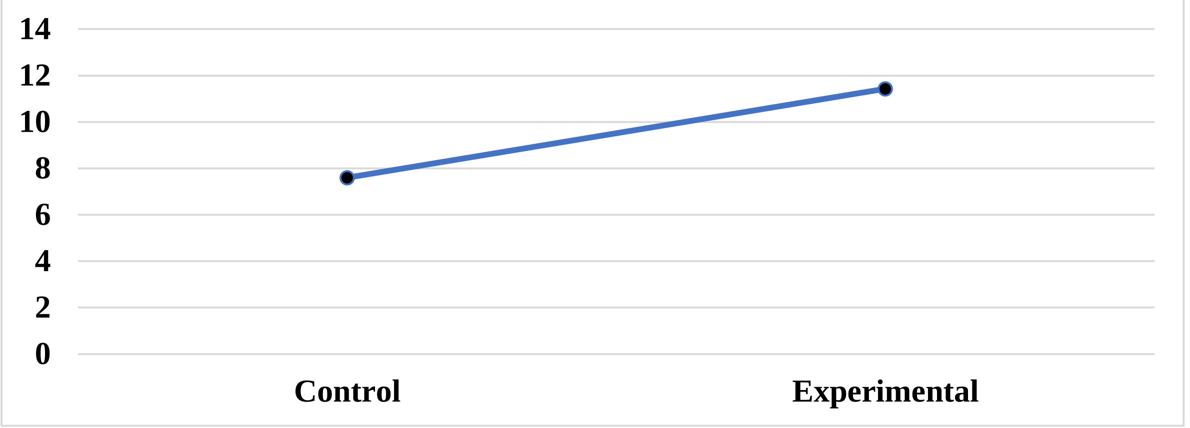

Figure 1

The differences between the mean scores of the two research groups in the posttest of the cognitive achievement

This result is consistent with what were stated by some of the results of previous research and studies (e Abdel Rahman, 2012; Al Dukain, 2015; Chiu, et al., 2015; Hazaa & Qutb, 2020; Hijazi & Ali, 2011; Ismail, et al., 2016; Yang & Heh, 2007) which highlighted developing cognitive achievement using virtual laboratories in various fields of science.

The superiority of the experimental group pupils over the control group ones in cognitive achievement may be due to many reasons. Among these reasons are the following:

- The use of virtual laboratories according to the constructivist theory makes the learner the focus of the educational process by activating his role. The student searches and implements activities, providing the learner with the opportunity to practice basic and integrative science processes, which raises the level of their knowledge acquisition.
- Virtual labs have overcome many of the obstacles to working in actual labs, such as the lack of materials and the poor availability of many tools necessary to carry out scientific activities and experiments in science.
- Virtual laboratories provided the most important element that the actual laboratories lack, which is security and safety, by reducing their exposure to chemicals, in addition to providing experiment or activity

more than once at school or at home, which raises their level of self-confidence and the growth of their cognitive achievement.

- Virtual labs are an active learning environment that urges the student to immerse himself in the tasks of learning activities for the purpose of acquiring new experiences and linking them to his previous experiences, and this is consistent with the principle of constructivist learning which states that the human mind is of a social nature.
- The issues and problems related to the content of the subject unit helped the students search for solutions through virtual labs in order to reach a level of deep understanding. This in turn contributed to the learning experiences that had an impact on their minds without resorting to memorizing and exposing them to forgetting. This interpretation is consistent with the principle of constructivist learning which confirms that the search for meaning is innate to the learner.
- Developing virtual labs in the light of the constructivist learning philosophy allowed students to play an active role in the learning process.
- Providing opportunities for cooperation between students during the practice of some tasks and activities through virtual labs develops a deep understanding of concepts, which increases their ability to comprehend them well.
- The students were keen to summarize the results of their activities in the virtual labs in a short form, including simple visual graphical diagrams, which led to functional coding or coding of their learning experiences, helping them to retrieve them easily when needed.
- The learning experiences in the virtual labs included eliciting cognitive and metacognitive processes in order to diversify the experiences of his interaction with them and reveal the extent of his sense. This belongs to the principle of constructivist learning, which states that learning includes conscious and subconscious processes.
- The diversity of warming-up methods for learning activities in virtual labs led to taking into account the individual differences between the students, which called on all the students to focus on the content of the lesson and the realization of their minds.

2- Results related to the effect of virtual labs on developing critical thinking in science:

To answer the second research question, which states: "What is the effect of using virtual labs on developing critical thinking skills in science for the third elementary graders in Al-Taif, Saudi Arabia?", and verifying the hypothesis associated with it, which states "there is a statistically significant difference at the level (α≤0.05). between the mean scores attained by the control group and those of the experimental group in the posttest of the critical thinking in favour of the experimental group pupils", the value of the t-test for the differences between the mean scores of the two research groups in the posttest of the critical thinking was calculated as shown in the following table:

Table 10
Means, standard deviations, "t" value of the differences between the mean scores of the two research groups in the posttest of the creative thinking skills (N = 60)

Skills	Groups	Total Score	Mean	SD	SD Error	F	t	Sig.	Effect Size (η^2)
Fluency	**Control**	20	**13.07**	**1.530**	**0.279**		**17.041**		**0.835**
	Experimental		**18.63**	**.928**	**0.169**				**Large**
Flexibility	**Control**	20	**12.40**	**1.404**	**0.256**		**16.793**		**0.829**
	Experimental		**18.07**	**1.202**	**0.219**				**Large**
Originality	**Control**	20	**11.57**	**1.716**	**0.313**		**16.401**		**0.823**
	Experimental		**17.70**	**1.119**	**0.204**	**58**		**0,05**	**Large**
Sensitivity to problems	**Control**	20	**10.73**	**1.818**	**0.332**		**16.871**		**0.831**
	Experimental		**17.53**	**1.252**	**0.229**				**Large**
Total score of the scale	**Control**	**20**	**47.77**	**3.256**	**0.594**		**32.161**		**0.947**
	Experimental		**71.93**	**2.518**	**0.460**				**Large**

To avoid the error of the first type, the researcher modified the significance level using Bonferroni Adjustment, where the significance level (0.05) was divided by the number of dimensions (4) to become the new significance level (0.013).

The results shown above reveal that there are statistically significance differences at 0.013 in favour of the experimental group pupils for each skill of the creative thinking skills scale as well as the whole test. Hence, the second hypothesis was accepted.

With regard to the values of the effect size caused by the independent variable in the development of creative thinking skills, the values were high for the creative thinking skills (fluency, flexibility, originality, problem sensitivity and the total score of the scale), respectively; This means that (84%) of the variance occurred with fluency skill, (83%) of the variance occurred with flexibility skill, (82%) of the variance occurred with originality skill, (83%) of the variance occurred with sensitivity to problems, and (95 %) of the variance in the level of creative thinking skills in sciences, all of them are due to the independent variable (default coefficient), and the following graph shows the size of the differences between the mean scores of the sample students in the post-measurement of the creative thinking skills scale.

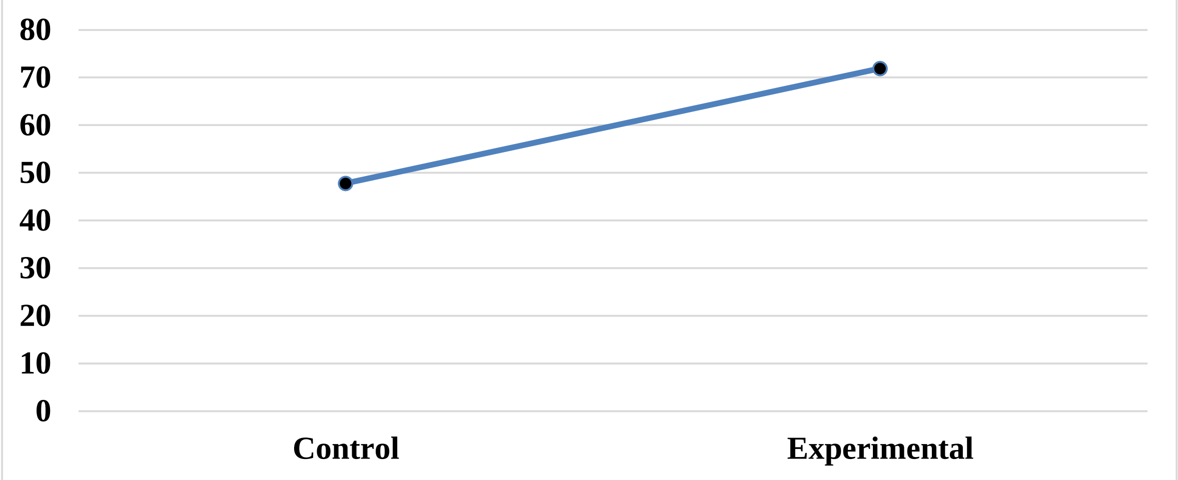

Figure 2
The differences between the mean scores of the two research groups in the posttest of the creative thinking skills

This result is consistent with what was stated by some of the results of previous research and studies, such as the study of (Al-Dakin, 2015; Al-Ghashem & Al-Hammadi, 2017; Qahm, 2021; Ramadhan & Irwanto, 2017; Trisnaningsih, et al., 2021; Usman, et al., 2021), from developing thinking skills in general and creative thinking in particular, using virtual laboratories in various fields of science.

The superiority of the experimental group pupils over the control group ones in creative thinking skills may be due to many reasons. Among these reasons are the following:

- The tasks of the learning activities in the virtual labs depended on visual and auditory learning, so the surrounding learning environment became stimulating to students' minds, and they were able to receive various stimuli and responded to them in a distinct way. This is consistent with the principle of constructivist learning which emphasizes that the learner's mind is an integrated system described as complex and at the same time dynamic, and this clearly contributed to the development of students' creative thinking skills.
- The virtual labs contributed to the students' repetition of experiments and scientific activities, without fear, and in a variety of ways, to the fluency and diversity of the students' ideas and the flexibility of their scientific thinking, which contributed to the growth of their creative thinking.
- The practical activities carried out in the virtual labs helped to analyze the tasks and reach tangible results in originality and flexibility, respectively. This was approved by the principle of constructivist learning in an explicit way that the mind of the learner has the ability to receive parts and colleges at the same time as it can produce them.
- The activities designed in virtual laboratories aiming at developing creative thinking skills in science took into account that the experiments and tasks put the students in a challenging position. This contributes to increasing suspense and excitement and enabling them to link their past and current experiences. This result is consistent with the principle of constructivist learning, which indicates that students' learning grows with challenge.
- Virtual labs helped develop some experiences that led to the growth of creative thinking skills in science, such as the availability of learning techniques that contributed to linking and integrating information. This interpretation is consistent with the principle of constructivist learning that growth and development are inherent in the learning process on an ongoing basis.

- The use of appropriate methods to enhance students during the stages of the virtual labs aroused thinking among the students and developed a spirit of challenge among them. This, in turn, had a great impact on the production of creative ideas and competition among them.
- The teacher's encouragement of students to elicit the benefits of the learning activities that they carried out in the various fields of life, led to training them on creative thinking skills such as fluency and sensitivity to problems.
- Virtual labs provide information about many enrichment activities. They are also considered as direct mechanisms for the development of creativity, through which students can expand their subject knowledge, and invent new ideas related to the subject, which may not be available in the textbook.

Recommendations:

Based on the study results, the following are recommended:

- Reconsidering the content of science curricula for the third grade of elementary school in the Kingdom of Saudi Arabia, to include activities and experiments that employ virtual labs to develop cognitive achievement and creative thinking, especially since both are essential requirements for understanding the scientific content and how to deal with it.
- Developing virtual science labs in light of the principles of constructivist learning, permanently used with school laboratories, contributing to the development of cognitive achievement and creative thinking skills for third-year pupils in elementary stage.
- Adopting a recent instructional strategy to use virtual labs to achieve science learning outcomes, by developing the tasks of science activities according to the principles of constructivist learning based on the availability of technology at any time and any place.
- Adopting the current research tools in exploring the levels of achievement of the third graders in science, and creative thinking skills.

Suggestions for further research:

Based on the results of the current research, it is suggested to conduct the following studies:

- The effect of virtual learning environments-based learning strategies on developing cognitive achievement and creative thinking in physics at the secondary stage in the Kingdom of Saudi Arabia.
- The effect of using virtual lab technology in light of the Covid-19 pandemic in developing the skills of comprehension and critical thinking in elementary school sciences in the Kingdom of Saudi Arabia.
- The effect of using the individual and cooperative learning styles in virtual labs and the timing of their use on the development of creative thinking and the trend towards elementary school sciences in the Kingdom of Saudi Arabia.
- The impact of virtual labs and school labs on students' achievement in chemistry and creative thinking in the secondary school in the Kingdom of Saudi Arabia: A comparative study

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