Journal for Educators, Teachers and Trainers
The PROFESIOLab electronic, peer-reviewed, open-access Magazine

ISSN 1989 – 9572

DOI: 10.47750/jett.2022.13.04.020

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Journal for Educators, Teachers and Trainers, Vol. 13 (4)

https://jett.labosfor.com/

Date of reception: 14 July 2022

Date of revision: 08 Aug 2022

Date of acceptance: 06 Aug 2022

Khalid Mohammed Alkhuzaim, Asmaa Muhammad Al-Qutaim (2022). The Effectiveness of an Enrichment Program in the Light of the Inquiry Approach in Acquiring the Nanotechnology Concepts and Developing Innovative Thinking Tendencies of Gifted Students at the Secondary Level in Al-Majmaah in the Kingdom of Saudi Arabia *Journal for Educators, Teachers and Trainers*,Vol. 13(4). 137 – 150.

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The Effectiveness of an Enrichment Program in the Light of the Inquiry Approach in Acquiring the Nanotechnology Concepts and Developing Innovative Thinking Tendencies of Gifted Students at the Secondary Level in Al-Majmaah in the Kingdom of Saudi Arabia

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ABSTRACT
This study aimed at identifying the effectiveness of an enrichment program in the light of the inquiry approach in acquiring the nanotechnology concepts and developing innovative thinking tendencies of gifted students at the secondary level in Al-Majmaah in the Kingdom of Saudi Arabia. To achieve the objectives of the study, a semi-experimental design was used. The sample of the study consisted of 42 gifted female students. The tools of the study included a test to measure the acquisition of the concepts of nanotechnology and an innovative thinking tendencies scale. The data was analyzed using a t-test and the eta-square test. The study found the presence of statistically significant differences between the average scores of the female students in the pre-and post-application of the innovative thinking tendencies scale and the students show more scores in using the pre-application of the scale. Moreover, there is a significant effect of the enrichment program in the light of the inquiry approach in developing creative thinking tendencies.

Keywords: creative thinking tendencies, enrichment program, gifted students, nanotechnology concepts, Saudi Arabia.

INTRODUCTION

Gifted people are considered as a national human wealth that must be invested appropriately. The development of nations is based on the achievement of its talented and creative individuals, and the educational services provided to gifted and creative learners are among the most important priorities in developed countries. So, it is necessary to work on investing their mental and creative energies positively. It was also indicated by Al-Saadi (2007), Al-Zahrani (2012), and Al-Ghamdi (2016) that gifted learners need many programs providing them with a wide range of ideas and information. This is in addition to their high mental abilities, especially in academic fields which call on specialists to design educational programs that suit their mental and intellectual characteristics, keep pace with the renewed knowledge revolution, and motivate them to innovate. Innovative thinking is based on some factors, including, experience, education, motivation, imagination, and personality. Most of the innovative thinking is attributed to internal factors such as genes, personality traits (thinking tendencies), value, cognitive skills, mind, and internal motivation. It is occasionally attributed to some external factors as education, economy, and culture. Both, internal and external factors work together to bring innovative thinking at its best. Gifted people need to be enriched regarding the latest developments and knowledge to expand the horizon of their innovative thinking and enhance their tendencies. The fields of technology are one of the most important areas to stimulate the trends of innovative thinking (Tolba, 2017) and nanotechnology occupies a prominent place on the list of scientific and research concerns in the developed world. The Stat Nano website was created in 2010 which is concerned with collecting, processing, and disseminating information about the development of nanotechnology in various countries around the world. It also provides information regarding the international and regional arrangement of countries and institutions in the field of nanotechnology based on various indicators (Statnano, 2022).

Educationists and researchers affirm that it is possible to develop thinking and innovation through the inquiry approach, as learners are placed in confusing situations, and are exposed to exciting questions to reveal a new idea or new meaning, through a set of ideas, facts, and information, either by themselves or under the guidance of the teacher (Nazer, 2014). Inquiry-based teaching strategies and models should be used which integrate the learner into systems or situations that require him/ her to explore strategies and procedures for solving the

problem and conduct investigation, discussion, and analysis (Lampert, 2006). The National Science Education Standards (NSES) that appeared in (1996) and the project 2061 indicated that scientific inquiry is the basis for learning science and that it is an essential factor in the achievement of scientific culture. A full understanding of scientific concepts cannot be achieved without engaging the learners in inquiry practices of questioning, problem identification, model building, use, and other practices (Nest Generation Science Standards, 2013).

Statement of the Problem

The unique properties of nanotechnology have made its education important for the learners, particularly the gifted among them because those students have special qualities. A national company has translated and adapted science books issued by the American McGraw-Hill company. Despite the efforts, there are still some shortcomings in the science curricula about the concepts and applications related to nanotechnology (Hafez et al., 2015; Al- Qateem, 2016; Al-Fifi, 2016; Al-Shalawi, 2018).

The results of an exploratory study that was conducted on a sample of 10 science teachers of gifted classes at Al-Majmaah Governorate showed that 100% of the teachers indicated that no enrichment programs or activities were provided for the gifted students at the secondary level to acquire the nanotechnology concepts. The findings also showed that 85% of the teachers indicated that no enrichment programs or activities were offered for gifted students at the secondary level which develop innovative thinking tendencies. However, 25% of the teachers indicated that there were various enrichment programs offered by King Abdul Aziz and his Companions for Giftedness and Creativity Foundation in the branches of Science, Engineering, and Technology during the summer program which may stimulate innovation.

Keeping in view the scope of the previous studies, the researcher felt the importance of providing an enrichment program in the light of the inquiry approach to acquire the nanotechnology concepts, and to develop innovative thinking skills among gifted female students at the secondary level. Many researchers like Johnsen (2011), Al-Nimr (2015), Ambusaidi (2015), and Al-Hindal (2016) found the inquiry approach as an appropriate approach to find the tendencies of the gifted students. Jan et al., (2001) also consider inquiry-based education as an essential component of science to enhance the learner's abilities and develop his/ her understanding of scientific concepts along with thinking skills and tendencies. So, there was a need to recognize the effectiveness of an enrichment program in the light of the inquiry approach.

Hypotheses of the Study

1. There is a statistically significant difference at the significance level ($\alpha > 0.05$) between the mean scores of the sample of the study in the pre-and post-applications for testing nanotechnology concepts in favor of the post-application.
2. There is a statistically significant difference at the significance level ($\alpha > 0.05$) between the mean scores of the study sample in the pre-and post-applications measuring the innovative thinking tendencies in favor of the post-application.

Research Objectives

The objectives of the study are:

1. To recognize the effectiveness of an enrichment program in the light of the inquiry approach to providing gifted female students at the secondary level with the nanotechnology concepts
2. To recognize the effectiveness of an enrichment program in the light of the inquiry approach in developing innovative thinking tendencies among gifted female students during the secondary level
3. To formulate a specific mechanism to benefit from the results of the study.

Significance of the Study

The study is a contribution to technical education vision that is compatible with modern scientific and technical developments. It is also an addition in the field of science enrichment programs in 'nanotechnology'. It fills the gap in Arab research studies in the field of developing innovative thinking skills. This study also proposes an enrichment program for gifted children at the secondary level that aims at providing learners with the concepts of nanotechnology and enabling them to understand the concept. It is also significant as it provides a list of appropriate nanotechnology concepts for gifted students at the secondary level. They can be used to measure the extent to which nanotechnology concepts have been acquired and to measure the students' innovative thinking tendencies.

Limitations of the Study

There are certain limitations of the study which include objective, temporal, spatial, and human limitations. This study focuses on providing an enrichment program only in the fields of nanotechnology and innovative thinking tendencies. Only the female students from the first semester of the academic year, 2019 have been focused. Further, the focus of the study remained the Gifted Center in Al-Majmaah Governorate, Kingdom of Saudi Arabia.

Theoretical Framework

The theoretical framework of this study is based on three domains, i.e., scientific investigation, Nanotechnology, and the trends of innovative thinking.

The First Domain: Scientific Investigation

Inquiry-based learning requires learners to be immersed in the work of science by its nature. Learning is not just a repetition of the topics and information they have studied. The inquiry-based education is not concerned with the amount of information that is stored at the moment, but rather with the ideas or concepts that have been formed (Ambosaidi & Al-Zoghbi, 2009)

The entrance in the human sciences is defined as a system of ideas derived from scientific theories in various fields that can be employed in educational processes (Awad, 2009). The increasing interest in the inquiry approach has led to the emergence of many inquiry models. One of the recent models is the inquiry wheel model or active inquiry model which includes 10 main activities. It is an activity of asking questions (Reiff, R, et al, 2002, pp. 12-19). Figure 1 shows the model.

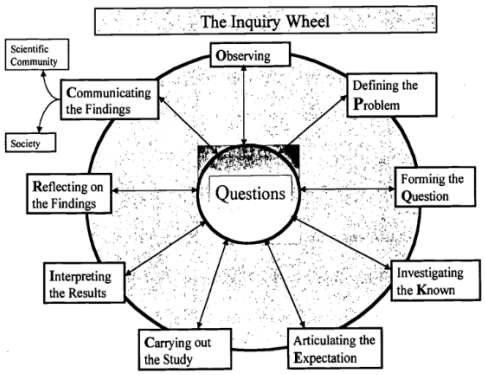

Figure 1: Inquiry wheel model
Fig. 1. Inquiry wheel model (Reiff et al., 2002, pp.12-19)

The inquiry wheel model is distinguished from other inquiry models, and the scientific method because of its ten activities and flexibility in moving between them. One can focus on the most needed activity. Based on the foregoisng discussion, the inquiry approach can be defined procedurally: it is a set of ideas derived from the constructivist theory which is concerned with providing the opportunity for students to explore questions of a scientific nature, search for evidence to answer them, provide explanations, evaluate those interpretations, find possible alternative solutions, and exchange conclusions with others. The effectiveness of this approach is proven by experimenting with its models, most notably the inquiry wheel model. The current study uses the inquiry domain and the inquiry wheel model to build the enrichment program and the teacher's enrichment guides.

The Second Domain: Nanotechnology

The roots of nanoscience and technology are the essence of scientific concepts that transcend barriers between traditional branches of science as physics, chemistry, and biology. Nanotechnology also reflects the characteristics of modern science and clarifies the relationship between the role of science and technology in society (Chih, 2006; Healy, 2009; Andrew, et al, 2011; Hingant & Albey, 2010). Al-Iskandarani (2010) defines nanotechnology as “advanced technology based on the rational understanding and study of nanoscience, with the technological ability to synthesize nanomaterials and control its internal structure, and restructure and arrange the atoms and molecules that it contains to obtain distinct products” (p. 25).

Mustafa (2013) also defines nanotechnology as the field through which materials and devices of shapes and sizes are designed, synthesized, and applied at the nanoscale. In this technology, the chemical, physical, electrical, and mechanical properties of the materials that are used in it are also exploited. Finally, it allows obtaining nano products.

The concepts that are related to nanotechnology are defined procedurally in this study. They are from the fields of environment, medicine, and energy which are appropriate for the content of science branches and gifted students in secondary school.

This technology is related to the fields of sciences like biology, chemistry, physics, and earth science, and it is also related to medicine and engineering. The chemist prepares a nanomaterial, the physicist studies its properties, the biologist investigates the changes caused by these nanomaterials all in one laboratory, the doctor

looks for nanomaterials for drug delivery, and engineer and environmental scientist look for ways to improve water and air purification processes, protect surfaces, and strengthen industries, making them more accurate with this technology.

In the United States of America, large-scale methodological initiatives have been undertaken and funded by the National Science Foundation and the National Center for Learning and Teaching in the Field of Nanoscience and Engineering. These projects include holding workshops and studies aimed at clarifying the pivotal elements in nanotechnology that should be included in the Science curriculum (Wansom, et al, 2009).

American universities also offer summer programs to enrich students and teachers on nanotechnology annually. Physics Department of Pennsylvania State University, and the Center for Nanoscience, in partnership with the National Science Foundation, are among those. The teachers of physics, chemistry, biology, technology, mathematics, and engineering design are encouraged to attend the program free of charge. Moreover, the workshops offer six-week work and there are also some research seminars on nanotechnology (Penn State University, 2018).

Many European countries have experimented with the mechanism of integrating nanotechnology materials into their educational curricula through several projects funded by the European Commission. Through these projects, many concepts are presented for curricula and modules needed to teach nanotechnology within science subjects (Sweeney & Seal, 2008). There are some initiatives in the Kingdom of Saudi Arabia. King Abdullah Institute for Nanotechnology is the one that enriches the students of the scientific and engineering departments (chemistry, physics, biology, mathematics, and medicine) at the university with courses in nanotechnology (King Abdullah Institute for Nanotechnology, 2022). The theoretical framework of the nanotechnology domain has been used in the formation of the list of nanotechnology concepts included in the enrichment program.

The Third Domain: The Trends of Innovative Thinking

Innovative thinking is affected by many sources and factors. The most important of them are internal factors, including innovative thinking tendencies which can be developed through educational systems (Al-Taher, 2015). Innovative thinking tendencies are defined as abilities, aptitudes, characteristics, and personal traits which are the inherent strength of innovation, and one of the main components of innovation and innovative thinking (Fasko, 2001).

Six sources have been identified that facilitate innovative thinking among students: intelligence, knowledge, mental style, thinking tendencies (personality), motivation, and environmental context (Sternberg & Lubart, 1991; Sternberg & Williams, 1997). In this field, Lucas et al (2012) sought to present a model that focuses on thinking tendencies, known as the five-stage model of innovative tendencies. The model consists of five basic tendencies of the innovative mind:

1. Inquisitive: This tendency manifests itself in wondering, astonishing, questioning, exploring, verifying, and confronting assumptions.
2. Persistence: It expresses insistence on challenging and repeating attempts to reach the solution or outcome to problems and ambiguous situations.
3. Imaginative: It expresses the individual's ability to reach solutions through imagination and innovative capabilities.
4. Collaborative: This is demonstrated by participating in the innovative output, giving and receiving feedback, and cooperating appropriately.
5. Disciplined: It appears when balancing the dreamy and imaginative side of innovation, and when knowledge and ingenuity are needed to shape the innovative output.

Lucas et al. (2012) concluded that these five tendencies are fundamental to innovative thinking and that it is necessary to use and reinforce them across different curricula. In each of these tendencies, there are three sub-trends associated with them. Figure 3 shows the basic tendencies, the five tendencies of innovative thinking, and a set of sub-trends. The sub-trends are formed from 15 tendencies, and for this reason, this model was adopted for this study.

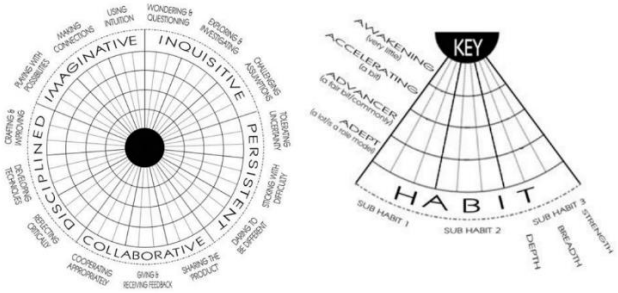

Fig. 2. The Five-Stage Model of Innovative Tendencies (Lucas et al., 2012)

Based on the foregoing, the tendencies of innovative thinking were procedurally defined in the current study. They are the personal strengths and factors of gifted female students at the secondary level that relate to tendencies (curiosity, perseverance, persistence, imagination, cooperation, regularity, and discipline) in the five-stage model of innovative tendencies. It is statistically measured by the degree obtained by the student on the scale of innovative thinking tendencies which was prepared for this study.

Literature Review

This section presents some Arab and foreign research studies related to the study of three domains: the first domain is the scientific investigation, the second domain is nanotechnology, and the third domain is the trends of innovative thinking. These domains were selected because of their importance in rooting the theoretical framework on which the study is based, building its tools, and comparing the study results that contribute to enriching and supporting the study.

While reviewing previous studies some points were considered according to the domains of the study. Firstly, the studies display a chronological order from the oldest to the most recent within the past ten years. Secondly, the research studies use a unifying methodology and show important results. Lastly, the literature review comments on the important findings of the studies.

Different research studies were conducted keeping in view the first domain of the scientific investigation. For example, Chen et al (2012) investigated the effectiveness of inquiry learning in teaching nanotechnology to primary school students. The study concludes that students' understanding of Nano concepts and applications in the experimental group increased about 23.63% over the control group's comprehension. It indicates the effect of inquiry teaching.

Likewise, Stephanie et al (2012) conducted a study that aimed at teaching students in the biology department using the inquiry wheel model and using that model during the study program and in laboratories and also measuring its impact on students' achievement. The results show that when Biology teachers use inquiry wheels in their teaching practices, it indicates a positive impact on the achievement of Biology department students.

Saleh and Al-Sayed (2014) also investigated the impacts of the wheel model and the problem-solving method in developing cognitive achievement, scientific investigation skills, and motivation to learn science for second-grade students in middle school. The results reveal the effect of the two independent variables (inquiry wheel model and solving method problems) in developing the dependent variables like cognitive achievement, practical inquiry skills, and motivation to learn science.

The current study converges with all the studies of this domain in the use of the inquiry approach (inquiry models or strategies) in teaching as an independent variable and the studies in the use of the quasi-experimental approach. The current study also converges with the studies of Stephanie, et al., (2012) and Saleh and Al-Sayed (2014) in terms of using the inquiry wheel model in teaching. The current study converges with the study of Chen, et al., (2012) also in its use of the survey approach as an "independent variable" and nanotechnology as a "dependent variable." The current study differs from the previous studies in the domain of environment in which the study was applied. The current study was applied in the Kingdom of Saudi Arabia while the rest of the studies of the domain were applied in Arab and foreign societies other than the Saudi society. The current study also differs from the studies conducted on the domain of the study community. The current study was applied to gifted female students at the secondary level in the Kingdom of Saudi Arabia, while most of the previous studies were applied to ordinary students.

The second domain, i.e., 'nanotechnology', is also studied by many researchers. For example, the study of Hafez et al., (2015) identified the extent to which the science curricula at the secondary level in the Kingdom of Saudi Arabia include appropriate concepts of nanotechnology. The results indicate that the percentage of the use of nanotechnology by the medical field, the general field, and the industrial field is 37.7%, 28.6%, and 20% respectively. It indicates that there is a lack of nanotechnological concepts in science curricula at the secondary level.

Al-Taqbi's (2017) study contributed well to the field of nanotechnology. Using the progressive inquiry model for developing conceptual comprehension, his study presented a unit in science keeping in view the concept of nanotechnology.

Al-Shalawi's study (2018) aimed at knowing the effectiveness of an educational program based on the interface to integrate nanotechnology concepts and applications. It also found its effectiveness in developing scientific thinking skills for secondary school students. The study concluded that there is a statistically significant difference at the significance level of 0.05 to test scientific thinking skills in Physics (3) in favor of the average post-application scores.

Mustafa's study (2021) also aimed at exploring the conceptual framework for "STEM" schools and identifying the concept of nanotechnology, its most important characteristics, and the importance of integrating it into the educational process. The study also aimed at knowing the application of this modern technology in educational institutions in general and STEM schools in particular. It also focuses on the challenges in using nanotechnology. Some of the challenges are that the teachers do not have any experience of using the concept of

nanotechnology and how to apply it in school education. Some of the reasons for not using it are weak educational capabilities, lack of advanced technological means in schools, and the lack of experts and specialists in schools to train students about the concepts of nanotechnology and its applications in school education. The study proposes an enrichment program to include nanotechnology in the educational process.

Like Al-Shalawi's (2018) study, the current study provides a program for acquiring the concepts of nanotechnology (the dependent variable). Moreover, like Hafez et al. (2015) and Al-Shalawi (2018), this study also explores a list of nanotechnology concepts, which allows the current study to be used as a guide in preparing a list of nanotechnology concepts. The current study converges with the studies of Hafez et al., (2015), and Al Shalawi, (2018) as far as the place of conducting the study is concerned. It was also conducted in Saudi Arabia. The study also converges with the study of Mustafa (2021) in terms of proposing an enrichment program to include nanotechnology in the educational process. As mentioned earlier, the current study differs from the previous studies in the domain of community, as the presents study represents gifted female students on the secondary level, while the rest of the studies were conducted on ordinary students.

Many studies were also conducted keeping in view the third domain, i.e., innovative thinking tendencies. Lucas et al. (2012) defined five dimensions of innovation that were assessed by teachers in two field experiments in the schools of England. Their study provides a theoretical basis for identifying and evaluating creativity, in addition to how creativity is developed and tracked in schools. The application of a five-dimensional model for the development of innovative thinking tendencies resulted in clear benefits. The results of the evaluation of the model show that it plays a crucial part in developing innovation among school students.

Ulger (2016) sought to determine the relationship between innovative thinking skills and students' thinking tendencies. His study represents the study community of students of the fifth semester at the university. Likewise, Al-Shammari's (2018) study explored the effect of a teaching program on the performance of first-year secondary school students. The study is based on the integration of the Needham constructivist model and self-organized learning in developing physical concepts and innovative thinking tendencies. The results reveal statistically significant differences at the significance level of 0.05 between the pre-and post-measurement of the teaching program that is the result of the integration of Needham's constructivist model and self-organized learning in developing physical concepts, and innovative thinking tendencies of the experimental group students in favor of post-measurement.

From the ongoing discussion, it is clear that the current study converges with Al-Shammari's (2018) study in the use of dependent variables and trends of innovative thinking. It also converges with the studies of Lucas (2012) and Al-Shammari (2018) in the use of study tools (the measure of innovative thinking tendencies of the five thinking tendencies model).

The current study differs from most of the previous studies in terms of the quality of presenting enrichment program. This enrichment program is for the secondary level, and further, it is not related to any specific class curriculum. The present study is also different from other research studies in terms of its construction in the light of the inquiry approach and the "wheel of inquiry" model. Moreover, regarding the content of its enrichment units, areas of nanotechnology concepts, and its activities and evaluation questions that target the growth of innovative thinking tendencies, it is unique in its scope. As far as the sample of the present study is concerned, unlike other studies that focus on ordinary students, it focuses on gifted students.

Methodology and Procedures

The current study uses an experimental method (the semi-experimental design), and it focuses on one group. The design of the experimental group is shown in Table 1.

Table 1. The Design of One Experimental Group

Random choice	The one experimental group G	pre-application of the nanotechnology concepts test O1 Pre-application of the innovative thinking tendencies scale O2	Treatment (the enrichment program in light of the inquiry approach) X	post-application of the nanotechnology concepts test O1 Post-application of the innovative thinking tendencies scale O2

The Sample of the Study

145 gifted female students from the first semester of the year 1439 -1440 AH from AL-Majmaah Governorate were selected as a sample for this study. The criterion was to pass the scale of the national project to identify the gifted. They were selected from 3 offices affiliated with the Education Department in Al-Majmaah Governorate. The distribution of the sample is mentioned in detail in Table 2.

Table 2. Distribution of the Study Population "Talented Female Students in the Secondary Level in Al-Majmaah Governorate"

Gifted office	Number of students
Al-Majmaah	67
Artawiyah	38
Hotat Sedir	40
Total	145

The sample of the study consisted of one group of talented female students at the secondary level, representing the study group. A multi-stage cluster sample was chosen, and it was selected according to the following steps:
At the first stage, the sample was selected randomly from the office of gifted students in Al-Majmaah. They were affiliated with the Education Department in Al-Majmaah Governorate. The office was selected among other offices affiliated with the Department. The second stage includes the random selection of secondary school students. The program was announced and registered by the gifted students randomly. The study group consisted of 45 female students who attended the program, and the results of 3 students were excluded due to their frequent absence. Only the results of 42 students were considered reliable. Those students represent 21.75% of the study population.

Variables of the Study

Following are the variables of the study:

- Independent variable: an enrichment program based on an inquiry approach
- The first dependent variable: Nanotechnology concepts
- The second dependent variable: innovative thinking tendencies

Research Tools

Testing is used as a tool for this study. Testing and re-testing the concepts of nanotechnology are conducted following different steps. The first step includes the selection of the nanotechnological concepts that should be included in the enrichment program. Table 3 shows the distribution of the inclusion of nanotechnology concepts for the enrichment program.

Table 3. The Distribution of the Inclusion of Nanotechnology Concepts in the Topics of the Enrichment Program Units

Program topics of the Units	The program's sub-topics for each meeting enrich	The concepts and terminology
Nanotechnology basics	Concept introduction	Nanoscience- Nanotechnology- Nano Scale- Nanomaterials-- Top down- Bottom up Nanotechnology Ethics -Nan toxicology.
	Tools and devices in nanotechnology	(SEM) -(STM) -(AFM)- (TEM)-" Nano Manipulator - Nano Assembler-
	shapes of nanomaterials	Quantum Dots- Fullerène- Nano Particules- Carbon Nanotubes– Nano Wires - Nano fibre
Nanotechnology in the environment	Environmental nanotechnology applications	Nanofabrics- Nano Foods - Lotus effect - Nano Filtration - Nano and the Pollution - Nanolithography - Intelligent Ink - Nano Processor - Space Elevator - Lap on ahip- Scaffolding- Artificial limbs-
Nanotechnology in medicine	Medical nanotechnology applications	Cantilever - Nano Biotic - Nano Robotics - Nano Dendrimer - Gold and Silver Bars- Nano Bandage - Lap on a hip- Scaffolding- Artificial limbs-
Nanotechnology in energy	Nanotechnology applications in energy	Nano Solar cells - Supercapacitors - Nano Fuel Cells - Nanomechanical amplifier - Nanotubes electrical circuits.

The second step is to determine the aim of the test. The test that is used in the current study aims to measure the acquisition of the concepts of nanotechnology of gifted students at the secondary level. These concepts are

included in the enrichment program at the two levels of the Davis model because these levels are most appropriate for evaluating the acquisition of concepts in the light of the constructivist philosophy and inquiry approach.

The Davis model evaluates the acquisition of the concepts on two levels to judge the extent to which the learner acquires the concept and his ability to use it. At the first level, it measures the learner's ability to distinguish between two things which are the examples, and which are not the examples of the concept while the second level measures the ability of the learner to distinguish the characteristics of the concept. The importance and relative weight of the test components were also determined in the preparation of the specification table, and the formulation of questions, which were represented in multiple-choice questions.

It was designed according to the Davis model and consisted of 43 questions. The test instructions were formulated. The correction key was prepared, and the test was validated by presenting it to some arbitrators who were specialists in this field. The test was modified in the light of arbitration and 44 items were taken. An exploratory experiment was also conducted to test and determine the appropriate time (35 minutes), and the coefficient of difficulty and ease of the test ranged between 22.7 to 79.5. It indicates that the test vocabulary is suitable for the aims of the study. The discrimination coefficient for the test questions ranged between 0.45 to 0.81 and it is considered as a good range. The internal consistency validity coefficients of the test for the first Davis level ranged between 0.538 to 0.780 and for the second Davis level between 0.452 to 0.704. All these show high stability correlation coefficients.

The innovative thinking tendencies scale was designed according to the following steps:

- The scale in the current study aims to measure the innovative thinking tendencies of gifted female students in the secondary level in the pre-and post-application of the enrichment program.
- The innovative thinking tendencies scale was based on some sources such as research studies and books that deal with building a scale for innovative thinking tendencies.
- Innovative thinking tendencies are defined from five dimensions which are the dimensions of the five-stage model of innovative tendency: inquisitive, imaginative, persistent, collaborative, discipline.
- The innovative thinking tendencies scale consists of 32 items. They represent the five dimensions of innovative thinking tendencies. Their statements are formulated on a five-point Likert scale (strongly agree, agree, neutral, disagree, strongly disagree).

Table 4. Degrees and Categories of the Five-Year Scale

Include options	value	Category
Strongly Disagree	1	1-1.80
Disagree	2	greater than 1.80-2.60
Neutral	3	greater than 2.60-3.40
I agree	4	Greater than 3.40-4.20
I totally agree	5	Greater than 4.20-5

- Drafting the instructions of the scale and determining the validity of the apparent scale was done by presenting it to some arbitrators specialized in gifted, creativity, and thinking. Their recommendations were incorporated.
- The exploratory experiment of the scale and the calculation of the stability coefficient, where the value of the total stability coefficient (alpha) reached 0.871 which is a high degree of stability, and the internal consistency validity was calculated, in which the correlation coefficients for the domains ranged between 0.463 to 0.704 which are good correlation coefficients.
- The scale, after verifying the validity and reliability, consists of 30 statements according to five domains.

Methods Used for Data Analysis

The methods used in statistical data processing are as follows:

1. Cronbach's Alpha stability coefficient was used to calculate the stability of the two study tools.
2. Pearson Correlation Coefficient was used to calculate the internal consistency of the two study tools.
3. Difficulty coefficient and discriminatory ability were used for test items.
4. T-test was used for the two correlated groups. It was used to study the differences between the pre- and post-application of the study group.
5. The Eta Square test was used to study the size of the enrichment program impact in the light of the inquiry approach in acquiring nanotechnology concepts and developing innovative thinking tendencies among the study group.

RESULTS AND DISCUSSION

To verify the validity of the first hypothesis, the testing of nanotechnology concepts was applied to the experimental study group. The Paired Sample T-Test was used. This is shown in Table 5.

Table 5. The Results of the Arithmetic Averages and the Paired Sample T-test and the ETA Square Calculation

Dimensions	Test	Number	Arithmetic mean	Standard deviation	Freedom degree	T value	Significance level	(η2)
Davis Level One	Pre	42	4.71	1.63	41	-	0.001	0.28
	Post	42	6.95	1.97		6.129		
Davis Level Two	Pre	42	17.90	3.89	41	-	0.001	0.41
	Post	42	24.62	4.28		9.037		
Total	Pre	42	22.62	4.88	41	-	0.001	0.43
	Post	42	31.57	5.56		9.253		

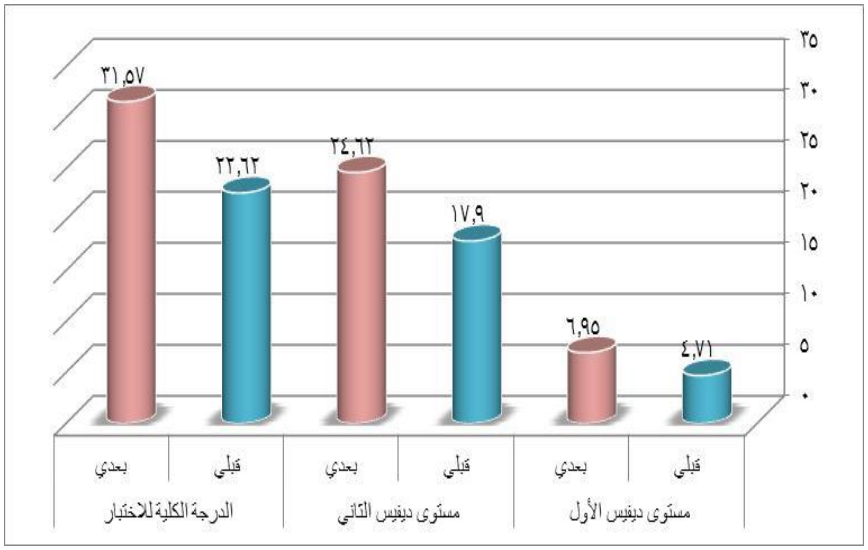

Fig. 3. Arithmetic Averages of the Pre and Post-tests for Secondary School Students to Test the Nanotechnology Concepts

Table 5 and Figure 3 show that there is a statistically significant difference at the level 0.01 between the average scores of the female students in the pre-and post-application of the nanotechnology concepts test concerning the total test score, in favor of the female students in the post-application with an average score of 31.57 compared to 22.62 for the students in the pre-application of the test. This difference between the mean scores of the students in the pre-and post-tests in favor of the post-test is due to the variable of teaching treatment which is the enrichment program. Table 5 shows that the value of the Eta square (η2) for the results of the pre-and post-application of the total degree of the nanotechnology concepts test is (0.43) which indicates a high influence of the independent variable on the dependent variable, showing that there is an effect of the enrichment program in the light of the inquiry approach to provide the nanotechnology concepts for gifted students.

The effectiveness of the result may be attributed to the enrichment program in the light of the inquiry approach to acquire the nanotechnology concepts for gifted female students at the secondary level. The nature of the enrichment program in the light of the inquiry approach made it possible to address the nanotechnology concepts in an interesting, active, and flexible manner. It takes into account the difference in the knowledge structure of gifted students, the nature of the scientific content of nanotechnology concepts, and the different skills, interests, and experiences of gifted women. The Next Generation Science Standards confirm that a full understanding of the science concepts will not happen without the learners engaging in the practices of inquiry from asking questions, defining the problem, building, and using the model. The other practices Nest Generation Science Standards (2013) and Bybee (2014) indicated that the inquiry encourages the student to challenge his/ her ideas to actively discover concepts. The inquiry wheel model which is used in the enrichment program for the gifted encouraged the challenge to discover the concepts of nanotechnology. In the current study, activities of the model support research and note-taking, and the communication activity in the inquiry wheel model support communication with the local and scientific community for the success of enrichment programs in the field of nanotechnology which is also consistent with what was recommended by Mustafa's (2021) study.

Giving students opportunities to communicate directly with experts in nanotechnology Nano or research centers to find answers to their scientific questions or support their research projects.

The relationship of nanotechnology concepts included in the enrichment program (environment field, energy field, & medicine field) with the current reality and the lives of gifted students increased their motivation towards acquiring concepts correctly. This was indicated by Mustafa (2021) that nanotechnology is one of the

fields of the age whose applications have abandoned the simplest details of daily life and topped the largest scientific inventions and innovations in various fields arousing the curiosity of students to know the basics of this technology and employ this knowledge in production, innovation, and problem-solving.

This result is in agreement with the findings of Chen, et al (2012) and Al-Taqbi (2017) who found the effectiveness of the inquiry in achieving knowledge of nanotechnology concepts.

To verify the validity of the second hypothesis, a measure of innovative thinking tendencies was applied to the experimental study group, in the pre-and post-application. A Paired Sample T-test was used. Table 6 shows the results in detail.

Table 6. Results of the Paired Sample T-test to Identify the Effectiveness of the Enrichment Program in the Light of the Inquiry Approach in Developing Innovative Thinking Tendencies for Gifted Female Students in the Secondary Level

Dimensions	Test	Number	Arithmetic mean	Standard deviation	Freedom degree	T value	Significance level	(η2)
Tendency to curiosity	Pre	42	3.81	0.51	41	-6.603	0.001	0.26
	Post	42	4.38	0.47				
Tendency to persevere and insistence	Pre	42	3.70	0.42	41	-7.480	0.001	0.37
	Post	42	4.33	0.40				
The tendency to the imagination	Pre	42	3.50	0.57	41	-6.663	0.001	0.35
	Post	42	4.30	0.51				
The tendency to Collaboration	Pre	42	3.67	0.51	41	-8.042	0.001	0.36
	Post	42	4.37	0.44				
tendency to order or discipline	Pre	42	3.67	0.41	41	-9.635	0.001	0.41
	Post	42	4.40	0.46				
The overall score for the scale	Pre	42	3.67	0.34	41	-11.179	0.001	0.54
	Post	42	4.35	0.29				

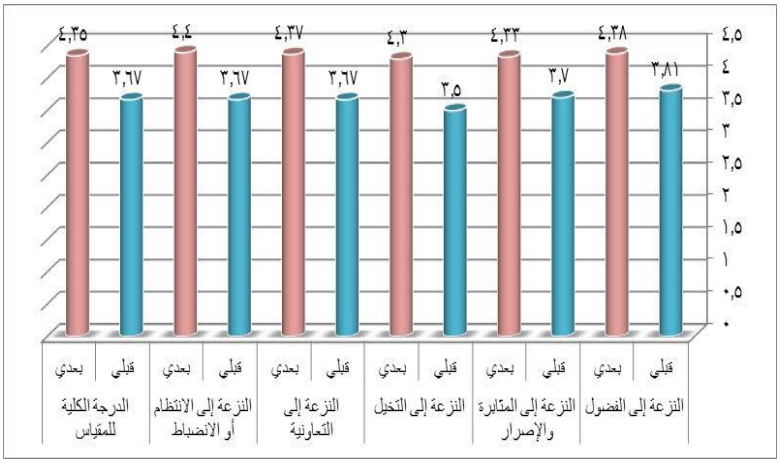

Fig. 4. Arithmetic Averages of the Pre and Post-Tests of Secondary School Students for the Inventive Thinking Tendencies Scale

The results in Table 6 and Figure 4 show that there are statistically significant differences at level 0.01 between the average scores of the students. The results in table 6 show that overall scores for the innovative thinking tendencies of female gifted students are 4.35 in pre and 3.67 in post-test. This means that female students show more scores in using the pre-application of the scale.

The results in Table 6 show that the value of the Eta square (η2) for the results of the pre and post-application with the total degree of innovative thinking tendencies reaches 0.54 which indicates a high impact of the independent variable on the dependent variable. This means that there is an effect of the enrichment program in the light of the inquiry approach in developing the creative thinking tendencies of gifted female students at the secondary level.

The effectiveness of the result may be attributed to the enrichment program in the light of the inquiry approach in developing the innovative thinking tendencies of gifted female students of the secondary level. The scholars emphasized that it is possible to develop innovative thinking in all its components. The most important of these are tendencies through the inquiry approach. Learners are placed in confusing situations and exposed to exciting questions to reveal a new idea or new meaning through a set of ideas, facts, and information, either by themselves or under the guidance of the teacher (Nazir, 2014, p. 17).

The inquiry wheel model used in the program depends on ten inquiry activities: defining the problem, formulating the question, discovering knowledge, forming an expectation, conducting the study, interpreting the results, reflecting on the results, communication, and observation. They are consistent with innovative thinking tendencies and characterized by flexibility as the student can return to any of the activities of the model.

The field of nanotechnology is a promising field that stimulates innovation and excites curiosity, discovery, research, and innovation challenge. So, the conceptual content of the program is of importance. The current study also takes into account the diversity of evaluation questions in the program to stimulate innovative thinking tendencies. This result was in agreement with Al-Shammari (2018) who found the effectiveness of using constructivist and inquiry teaching models in developing the innovative thinking tendencies among the experimental groups. It also agreed with Ulger (2016) and Al Shammari (2018) on the importance of developing innovative thinking tendencies.

Recommendations

This study recommends the inclusion of a list of nanotechnology concepts in the gifted curricula by the gifted curricula developers, as a modern technology from the fourth industrial revolution application areas. The is also a need to include the enrichment program which has proven effective in providing the nanotechnology concepts and developing innovative thinking tendencies among the sample of the gifted female students in Al-Majmaah Governorate, in the basic gifted enrichment programs in the Saudi Arabia Kingdom. It is also recommended to prepare specialized training courses for teachers of gifted female students at the secondary level to enable them to present the enrichment program in the light of the inquiry approach to acquire nanotechnology concepts and develop the innovative thinking tendencies among the gifted students at the secondary level. The study also recommends that the science laboratories in gifted centers and schools should be equipped with the necessary tools and materials to support experimentation and discovery in the field of nanotechnology. This study further emphasized on presenting its results to the Gifted General Administration to get benefit from the program, implementing the program in some regions of the Kingdom of Saudi Arabia and measuring its effectiveness using the tools that were prepared in the current study, and coordinating with the King Abdullah Institute for Nanotechnology as well as the other research centers in the field of nanotechnology to support the enrichment program.

Recommendations for Future Research

We recommend preparing a series of enrichment programs in the light of the inquiry approach to provide the concepts and applications of nanotechnology for the gifted in the general education stages which suits the age characteristics of each stage to make them aware of this new technology and to stimulate their innovation tendencies. Further research needs to be conducted to study the suitability of science laboratories in gifted schools to implement enrichment programs in the field of nanotechnology. Future research can study the level of nanotechnology awareness and its applications among science teachers and the extent to which it is related to certain variables such as years of experience, training, and specialization.

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