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Research Article

Schwartz's model-based instructional design for chemistry education: Effects of high school students' creativity

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Abstract

This study aimed to investigate the effect of the Schwartz's model on chemical concepts acquisition, improving creative thinking skills, and learning transfer of the ninth grade students. Participant of the study consisted of (64) ninth grade students from the Directorate in Amman, academic year (2018/2019), and they were divided randomly into experimental and control group. To achieve the objectives of the study, a teacher's guide for the electrochemistry unit was prepared using the chemistry curriculum for the ninth grade. Furthermore, creative thinking skills and chemical concepts were combined according to the Schwartz's model, and the chemical concept test was prepared in the form of a multiple choice test and test learning effect transfer. Also, the Torrance Test of Creative Thinking was prepared. Data were analyzed using ANCOVA, ANOVA and results showed the effectiveness of the Schwartz's model of chemical concepts, improvement in creative thinking skills, and transference of learning effect in favor of the experimental group students, and statistically significant difference was seen (α = 0.05) between the average performance of the study sample and in favor of the experimental group students. In light of the results, the study recommended the need for science students to use the Schwartz's model in teaching.

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Introduction

Modern education aims to teach students how to learn, think and quest for knowledge, with the aim of bringing up a generation who desire constant self-education, and the acquisition of thinking skills especially creative thinking, which are suitable for various growth stages. Science curricula is highly relevant in education, as students' results in science competitive tests on a global level, measure students 'levels of thinking, which confirms the importance of science curricula in the development of nations. These encourage countries to develop science curricula and adopt modern teaching strategies that are commensurate with the nature of science learning and education. (Ambosaidi & Al Balushi, 2011). Moreover, advanced methods and strategies in science teaching that help bridge the gap between new knowledge and scientific knowledge possessed by students are adopted.

Many schools around the world tend to expand the use of thinking skills in teaching students to create a "culture of thinking" outside of school and in all aspects of a student's life. Therefore, countries focused on forming "schools of thinking", a concept introduced by the Prime Minister of Singapore in 1997. At the 7th International Conference on Thinking, his idea was that all Singapore schools would become schools of thinking, thereby making Singapore a "Learning Nation" (Saravanan, 2005). Six other countries since then have adopted the same idea and model of incorporating thought by Schwartz, including New Zealand, Northern Ireland and Israel (Zohar, 2008; Gallagher et al. 2012; Swartz & McGuinness, 2014).

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Scientific and chemical concepts are one of the results of science and organized scientific knowledge, given the role of scientific and chemical concepts in building scientific generalizations, in addition to being abstract, which leads to difficulties in their development for some students as the process of building and improving scientific concepts for students - at different educational levels. It requires an appropriate teaching style, so it has become imperative to search for teaching strategies and methods that make the concept easy for students and help teachers teach scientific concepts (Ikramettin, 2016). Based on global efforts to strengthen societies in developing and competing with acquisition of scientific knowledge, which prompted research to develop methods of acquisition for scientific concepts and ways of thinking to maintain the impact of learning. For this reason, reform movements and global projects for scientific education arose, with Project (2061) being the most famous), which developed a future vision for the reform of science curricula in the states. The project focused on what students should know and what they are capable of doing (Zaitoon, 2010).

Boutros (2008, 59) defined the scientific concept as: "the grouping of things based on the characteristics of this group compared to other groups." Scientific concepts are the basis for building scientific principles, rules, laws and theories that describe and explain scientific phenomena. The concept learning process is divided into two stages, the first: building the concept, and the second understanding the concept. This process requires reflection, thinking, revision and modification by the learner, and builds on his knowledge so that it becomes useful in new situations and problem solving (Zaitoun, 2007). The science teaching process depends on two basic points: (Conceptual Understanding), and (Processes Procedural), and the teacher must get to know the conceptual structure of the learner, which allows him to choose the appropriate strategy for learning, and this makes the new topic understandable and facilitates the learning effect for the learner better (Al-Khalili, Haydar & Yunus, 1996). This is an important task for the teacher who wants to improve the scientific concepts of his students, the responsibility of choosing instructional strategies that help learners to link concepts and understand them comprehensively (Ross & Willson, 2012).

Building scientific concepts is the basic rule in science education and one of the most important goals of science education under the various educational stages. It is considered the basis for understanding the structure of the sciences, as it enables the individual to develop adequate mental insights towards phenomena and things, in order to become meaningful, and it is the basis for thinking and acquiring scientific knowledge, which requires an appropriate teaching method that ensures the integrity of concept formation and retention, and the transference of learning effect, it links cognitive facts with strong links through the qualities and characteristics of the concept, so it sticks in their heads. This helps the transference of learning effect and allows for the organization and linking of groups, making them easier to understand and retain than separate parts (Pabellon, 2005). Roozkoon (2013) explained that the learning process is an active, interactive process, in which the learner relies on his previous knowledge to build new experiences, relationships and connections, with his motivations to face many situations that require the use of his previous experiences to reach cognitive equilibrium, this will not happen unless the learner's ideas are linked to the concepts in his knowledge structure, as these concepts form the mental pillars that work on linking and integrating the previous knowledge with the new. The progress of societies depends on their ability to prepare creative individuals who are able to think. Therefore, developing students' thinking abilities has become one of the most important educational goals to be achieved in science education. Therefore, modern science curricula have tended to play their role in developing students' thinking and linking the thinking process with their performance skills.

Thinking is defined as "*processing mentally tangible inputs in order to construct ideas, and perceive, categorize and judge influences"* Costa & Kallick, (2001), and Jarwan, (2012) defined it as: "*A successive series of mental activities carried out by the brain, and creative thinking is a complex thinking closely related to the ability to imagine. It entails the person with the highest level of creativity in various activities, and is capable of moving away from the usual ways"*. The process of creative thinking does not happen suddenly or in one step, as this process passes through the highlighted stages Torrance, (1972) & Saadeh, (2015) as follows:

Preparation stage: In this stage, the brain prepared for creative thinking is active, and the information and ideas related to the issue at hand are gathered and properly understood.

The incubation stage: At this stage, the ideas related to the issue are organized, and the brain works to uncover the links between near and far objects, work to arrange them, and get rid of ideas that are not related to the issue.

The stage of inspiration or illumination: It is a stage in which the brain reaches a solution suddenly, during which an in-depth analysis of the problem is carried out, in order to reach the perception of the relationships between its parts, which allows the spark of creativity. This means the emergence of a new idea or an appropriate solution to the problem.

Verification stage: It is a stage in which the creator certifies his new idea, as he examines and tests the idea he arrived at in terms of its novelty, originality, and real usefulness, in preparation for its documentation and publication.

According to the Schwartz's model, integrated creative thinking consists of the following skills:

Idea generating skills: giving alternative possibilities, enumeration of ideas (fluency), diverse ideas (flexibility), new ideas (reporting), detailed ideas (development), and gathering of ideas: which include analogy or metaphor. Bernardo and Zhang (2002) emphasized the need to pay attention to students' creative thinking, given the changes and developments that societies are exposed to, which calls for the need to exploit human beings' creativity in problem solving.

The interest in creativity comes in response to an essential need for creative individuals, such as the tendency to gain independence, exploration, curiosity, exploring the unknown, discovery, and experimentation. Transference of learning effect is an important topic because it is one of the objectives of education, and it has multiple definitions, including the following: The effect of an individual's learning of a situation or form of activity on his ability to act in other situations or on his ability to perform other types of activity.

Baldwin & Ford (2006) confirmed that effective teaching strategy is: The strategy that allows students to gain experiences of various kinds of facts and concepts, and the ability to apply them practically which is different from classroom situations. They also confirmed that learning effect or the transfer of skill is determined by the learner's ability to transfer what he has acquired to real life.

The transference of learning effect is an educational goal, and Bereiter (1995) believes that the transference of learning effect is the learner's underlying ability to transmit what he has learned over his practice. Bereiter also asks teachers to focus on the features of education, which causes the learners to think about situations rather than repeating what they have learned. He emphasizes teaching students through group practices, while moving gradually to their own way of full practice. In response to developments and reform movements in methods of learning and teaching, several trends have emerged in teaching thinking as follows:

The first trend: direct teaching of thinking and calling for teaching thinking skills independently of the content of the school subjects, using free knowledge content independent of the subject matter. "CoRT" is one of the most popular programs that teach thinking directly.

The second trend: education for the purpose of thinking and calls for teaching implicit thinking processes during the teaching of the course.

The third trend: integration thinking, which means teaching one of the thinking skills directly within the context of the content and lessons of the subject matter. Thinking develops better through its integration into the curriculum and enhances the learning effect, which enables students to apply thinking in new situations. Teaching thinking includes employing several methods that are used to enhance students' deep understanding of the content, these methods include cooperative learning, graphic organizations, high-level questions, philosophical conversations, manual skills, and learning through questions (Swartz & Perkins, 2003).The more correct teaching thinking across the curriculum is reinforced, the higher students are more likely to engage. Thinking habits that we try to teach them in all ways of thinking that they use and teaching through thinking maps leads the learner to the actual participation in the formation of an interrelated thinking and cognitive structure linked to a basic concept, thereby, providing a collective educational environment.

Schwartz's model relies on combining effective techniques in the classroom when the goal is to make students good thinkers and effective strategies. Engaging students in learning can depend on integrating thinking skills and concepts in the academic content and the model seeks to make sound thinking an educational goal for all students to reach, as the model confirms. On the ability of teachers to help students think better. Incorporating thinking skills throughout the school curriculum also help students get a deeper understanding of the cognitive content of the subject, in addition to constantly revitalizing the study material, and increasing opportunities for students to learn to think well.

Improving students 'thinking through the Schwartz model depends on the following:

The more explicit the teaching of thinking, the better it affects students.

Also, the general teaching atmosphere in the classroom is characterized by the work of the mind and active thinking.

Students are able to reach the best way of thinking.

By integration between the thinking process and the content of the subject matter. The more students think about the content of the subject, the higher the achievements gained in an enjoyable and effective environment.

One of the most important characteristics of the Schwartz model is raising the level of students' comprehension and understanding of educational materials, which leads to improving learning processes, developing students' mental capabilities and acquiring skills, mental processes and habits that make them productive, and the model leads to raising the level of student's achievement and improving continuous self-learning. A blended learning strategy has many benefits.

It provides the important organizational questions that must be incorporated into the lesson. It introduces students to their ways of thinking and urges them to monitor their thinking. This helps them to play a positive role in collecting, organizing, integrating, follow up and evaluating information during their learning process. It also encourages students to recognize that group thinking helps in reaching ideas that the student alone may not reach, and this help model meaningful learning (Swartz & Perkins, 2003).

A blended learning strategy includes several teaching methods to enhance students' understanding of content, most notably cooperative learning, graphic organizers, high-level questions, philosophical conversations, education through questioning and manual skills. Lessons are designed in four steps according to Schwartz's model

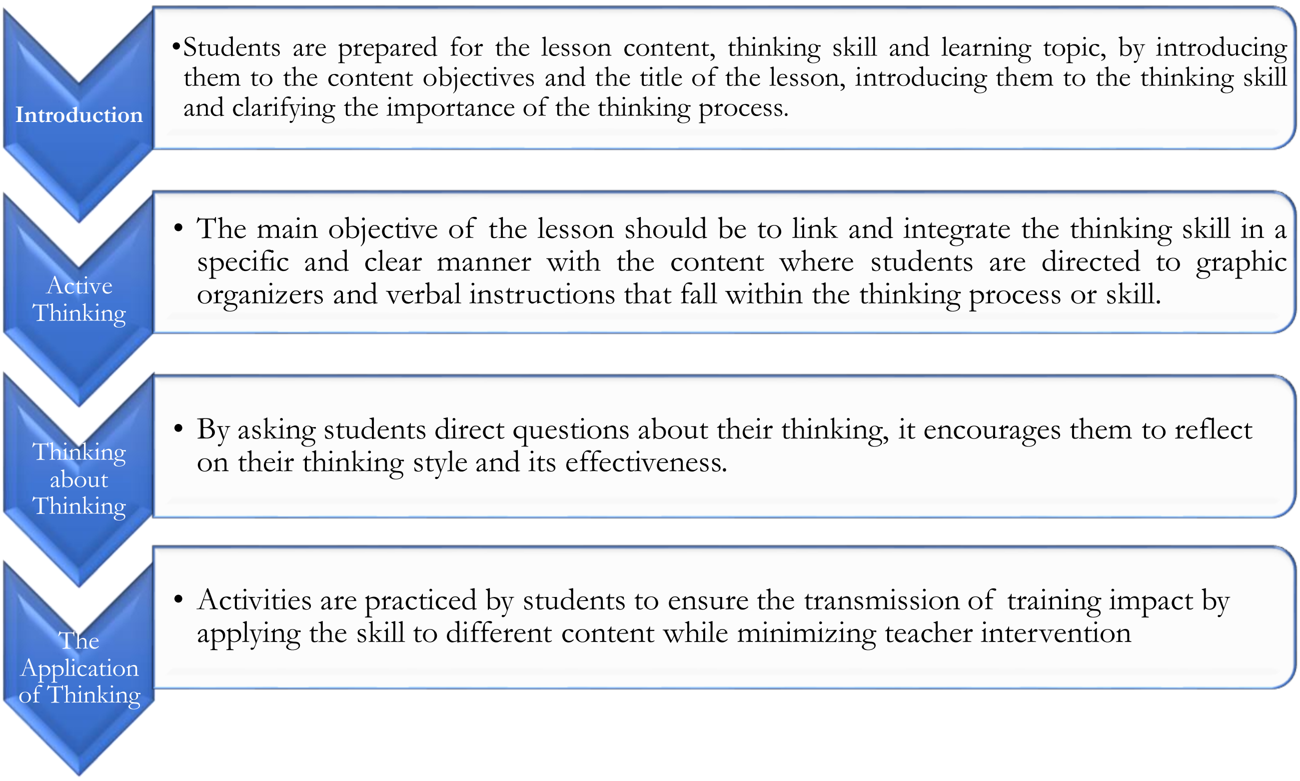

Figure 1. *Stages of Swartz 's Model (Swartz & Park, 2005).*

Students are assessed by presenting oral and written work and practical projects that demonstrate the extent to which the skill and the thinking process is used (Swartz & Park, 2005).

The general framework of science curricula in Jordan indicated the need for science curricula to focus on developing students' thinking skills and linking science education with the culture and reality of society and higher thinking skills. From here, we find that teaching thinking has a priority, especially providing students with creative and scientific thinking skills by blending thinking skills into the content; this contributes to achieving the required educational standards and produces students who are masters of the content of scientific subjects.

Swartz et al. (2008) explained that one of the priorities of the efforts in education reform is to improve the quality of thinking among the learners. Sound thinking is important in addressing life's challenges because it enhances the skill of decision-making, problem-solving, comparison and interviewing. The teaching of thinking skills is a structured process that needs planning from the teacher in order to teach students how and why they implement thinking skills. Educational schools have adopted two paths in teaching and developing thinking: teaching thinking independently within contexts outside the curriculum or blending thinking into the curriculum by reconstructing how the content of the traditional curriculum is used in the educational process (Swartz & Park, 1994).

Schwartz presented a model in teaching thinking skills based on the combination of educational content and thinking skills, using thinking maps and graphic organizers that confirm students' participation in activity-based educational situations where teaching content and thinking skills are one, and advocates of the blending trend believe that transference of learning effect is poor when teaching thinking using programs independent of the content. Also, the students feel anxious and alienated as a result of their learning in a way that differs from the usual method, while thinking develops better if it is incorporated into the academic content. This requires teachers to design lessons where thinking skills and curriculum content are taught simultaneously. Students are explicitly introduced to the most adept reasoning strategies, and then urged to use these strategies to reflect on the content they are learning. By focusing on higher-order thinking skills in content instruction, a deeper understanding is reported, as well as better writing, and an increased interest in what students are learning. When the infusion is accompanied by the introduction of explicit thinking strategies, along with highly-supported guidance by the teacher, pushing students beyond knowledge and thinking, there are numerous reports indicating the success of the Schwartz model in teaching blended thinking (McGuinness, 2006; Dewey & Bento, 2009; Burke & Williams, 2008; Spain De Acedo Lizarraga et al. 2010).

Learning chemistry concepts is not easy, and many students fail to develop an appropriate understanding of chemical concepts and transfer of learning effect, this may be due to their low levels of scientific thinking, and the teachers' failure to use effective teaching methods that are capable of overcoming the difficulties they face in teaching science. Since the method of teaching is important in learning and acquiring concepts, retaining and transmitting of learning effect in addition to providing students with thinking skills, the teachers' familiarity with general and special teaching methods and effective methods and models aimed at increasing their achievement.

Based on the foregoing, and in view of the importance of improving the acquisition of chemical concepts and thinking skills and the transference of learning effect, and through the researcher's acquaintance with the studies related to the use of science teaching strategies, we know the importance of adopting modern strategies that are concerned with thinking skills and meaningful learning, especially since most of the previous studies dealt with the topic of teaching thinking in programs independent of content, those that focused on blending thinking skills with the content of school subjects are still limited according to the researcher's knowledge, hence the need for this study to investigate the effect of teaching chemistry using the Schwartz model in acquiring scientific concepts, improving creative thinking skills, and transference of learning effect on the ninth grade female students in Jordan.

Significance of the Study

The theoretical significance of the study stemmed from the following fields:

- It provides measuring tools with psychometric properties, and a teaching method based on the Schwartz model that researchers may benefit from in future studies. Moreover, it enriches Arab literature, as the study provides a theoretical framework and field application in the two fields of the Schwartz model by blending thinking skills into content, to teach science in the acquisition of scientific concepts, the development of creative thinking skills and the transmission of the learning effect.
- Helps teachers become familiar with modern teaching strategies based on the Schwartz model, and training on how to apply them and integrate thinking skills into content, which increases the effectiveness of teaching in the field of science.

Application Significance

The practical significance of the study stemmed from the following:

The results of the study provide science curriculum developers in Jordan with indicators to determine the effectiveness of the blending thinking skills method in teaching science, in order to be adopted in these curricula for teaching. The results of this study may provide those in charge of qualifying and developing teachers during their service in the Ministry of Education, with new information and models that may contribute to helping them set up training programs that increase the efficiency of teachers.

It provides a test of scientific concepts, a test for creative thinking, a test for the transference of learning effect, and a guide for the teacher prepared according to scientific steps that science supervisors and teachers may benefit from when carrying out their educational tasks, and students of scientific studies in the field of science curricula when preparing their research tools.

It represents a new addition to studies in the field of creative thinking and the transference of learning effect using the approach of inclusion in teaching thinking skills and content and highlighting effectiveness of the method of blending thinking skills in the curriculum content as well as directing those interested in the importance of teaching thinking through inclusion.

The results may also provide feedback for science teachers by developing their performance and improving their teaching skills and by adopting modern strategies and models in teaching science.

Procedural Definitions

Schwartz model: It is a model for teaching thinking by blending, and it focuses on combining theoretical information with the various forms of thinking that the student uses in his daily life. The blending lesson consists of four parts: Introduction; It displays the content, skill, process of thinking, and active thinking; Where the skill of thinking is linked and integrated with the content through the use of graphic organizers, verbal instructions and reflection thinking; It includes directing students to reflect on the thinking pattern that they adopted during the active thinking and application of thinking stage; It is a set of activities for imparting training that includes the student's automatic use of the skill of thinking in other contexts.

A student-centered learning model that aims at mastering the learning processes and organizes a set of thinking skills and processes into categories: comprehension and comprehension, creative thinking, critical thinking, decision-making and problem-solving. In each category, there are a set of skills and thinking processes, and it clarifies the strategies for performing each skill and process and how to integrate them into Teaching courses and teaching, using several methods (Swartz et al. 2008).

- McGuinness & Swartz (2014, 6) defined it as "thinking skills integrated within the curriculum that include analyzing arguments, proofs, finding causes and consequences and uncovering the assumptions behind every piece of information presented to the student."
- The study unit developed according to the Schwartz model: It is the electrochemistry unit from the chemistry textbook for the ninth grade in Jordan, which was developed according to the Schwartz model and was implemented in 18 lessons.

Chemical concepts: Zaitoun (2010) defined them as “what an individual has in terms of meaning and understanding related to a word, term, phrase, or process” (pp. 233). In this study, chemical concepts are mental perceptions resulting from the perception of the relationships, elements and common symbols between a group of phenomena. Or the events included in the subject of the electrochemistry unit, expressed in terms or a term with chemical significance within the subjects that students of the ninth grade will study according to the Schwartz model and the usual method of teaching, and the acquisition of these concepts was measured by the score obtained by the student in the chemical concepts test of the ninth grade Which was prepared in this study.

Creative thinking: Torrance (1965) defined it as "*a mental process in which the individual possesses a high degree of sensitivity to problems, deficiencies, knowledge gaps, missing elements, contradictions, etc., and the ability to identify difficulties; search for solutions, developing guesses or formulating hypotheses about deficiencies* (663), testing and retesting these hypotheses, and perhaps modifying and re-testing them, and finally reaching conclusions. It can be defined procedurally by the overall degree obtained. The student in the Creative Thinking Test, which was developed for the purposes of this study, is compatible with the Torrance Verbal Form A test, and is adapted to the Jordanian educational environment and chemistry subject.

The survival of the learning effect: This is measured by the learning effect test prepared in this study and it entails the extent to which the learner maintains the chemical concepts after three weeks of the study (Jassim, 2000).The researcher knows the extent to which the learner retains the information, skills and chemical concepts that will be studied using the Schwartz model in the electrochemistry unit in the ninth grade chemistry book for a period of time within four weeks, and this is measured by the degree obtained by the student in the transference of learning effect test that was prepared by the researcher.

Ninth grade students: all students enrolled in the academic year (2018/2019) at Laila Al-Ghafari School, affiliated to the Directorate of Education for the Marka District in the Capital Amman Governorate, and their ages range between 14-15 years.

Theoretical Framework and Previous Studies

School curricula, especially science curricula, seek to prepare the citizen to interact with his contemporary reality effectively, and because science curricula consist of scientific knowledge represented by facts, generalizations, principles, laws, scientific theories, and various thinking skills, it was necessary to emphasize the learners’ acquisition of scientific concepts, the development of thinking and the transmission of the learning effect. They experience it in their daily life.

Zaq & Hajj Hajjah (2015) conducted a study on the effect of a training program (based on the Schwartz model) in thinking, developing decision-making skills among seventh-grade students, and the study followed the experimental approach, and the results showed the following: the Schwartz model effect in developing decision-making skills and validity in skilled thinking.

Darawsheh and Al-Ayasrah (2014) conducted a study on the effect of designing a unit of study in science based on the Schwartz model of improving critical thinking and creative thinking skills among fourth-grade students. The study followed the quasi-experimental approach, and the study showed statistical significance at 0.05 α between the average scores of the control group students and the experimental group in the critical thinking test attributable to the developed study unit and there was no statistically significant difference at 0.05α between the average scores of the control group students and the experimental group in the creative thinking test attributed to the developed study unit.

A study by Weiping et al. (2011) aimed to describe and evaluate the theory of learning based on thinking outside the curriculum, and teaching thinking through blending and Schwartz model. The study sample consisted of 166 students in three classes; in Chinese school, and all students were subjected to a non-verbal intelligence test, and academic achievement prior to the implementation of the study, and then the students were subjected to the activity of teaching thinking every two weeks for a period of four years, and the results of the study showed an increase in the ability to think, after a year had passed in the first and second grades, and after six months had passed for the third grade. There are better positive effects of teaching thinking skills and academic achievement.

Dewey & Bento (2009) study aimed to verify the effectiveness of Activating Children's Thinking Skill (ACTS) among fourth to sixth grade students by developing their cognitive thinking skills, social and emotional skills. The study included (404) students from Northern Ireland schools. The results of the study showed that students of the experimental group excelled in the scale of cognitive thinking skills, and in the scale of social and emotional skills.

Fathallah (2009) conducted a study on the impact of the strategy of thinking maps based on integration on the development of achievement in the subject of science and critical thinking and the trend towards cooperative work among middle school students in the Kingdom of Saudi Arabia. Achieving the goal of the research required defining a list of scientific concepts, critical thinking skills, and the components of the trend towards cooperative work and teaching practices for the strategy of thinking maps based on inclusion, preparing a test in the achievement of scientific concepts, a test on critical thinking in science and a measure of the direction towards cooperative work. The sample of the study consisted of first-grade middle school students in two schools from the city of Onaiza, chosen randomly, with the number of students totaling 73. The results of the research resulted in the following: 1) The presence of a significant impact at a level less than 0.01 or equal to the development of critical thinking, achievement in science, and the trend towards cooperative work for the benefit of the experimental group versus the control group. 2) The impact size values of teaching also obtained with a strategy of thinking maps based on integration in the development of achievement, critical thinking, and the trend towards cooperative work is great.

In view of the previous studies and the researcher's acquaintance, the topics varied as they dealt with various strategies and approaches to teaching thinking, adopting the quasi-experimental approach and making use of them in the research method. This study differed from previous studies in that it dealt with the development of creative thinking, the acquisition of chemical concepts, and the transference of learning effect together, and their application to the ninth grade, while most studies tended to apply the Schwartz model on a younger age group.

Study Problem

The "National Tests for Quality Control of Education" showed a low level of student achievement in the science curriculum, as the arithmetic average of students' performance in eighth grade in the science curriculum reached 49% in 2014/2015 (Ministry of Education, 2015). The results also showed students' weakness in employing critical thinking, creative thinking and problem-solving skills in various science subjects (Abu Wazna, 2017). The results of the International Study in Science and Mathematics (TIMSS) for the year (2016) showed a clear decline in the level of Jordanian students in the fields of science and mathematics in general, and different areas of thinking in particular (Ministry of Education, 2017). Despite the Hashemite Kingdom of Jordan's efforts to improve students' performance in science, previous results in TIMSS tests are indicative of the need to reconsider the strategies and teaching methods of science.

Furthermore, a weakness in acquiring scientific concepts was observed among students, especially chemical concepts, and most of them encounter difficulties in learning scientific and chemical concepts in addition to their weakness in handling scientific concepts in their daily lives as Rajab (2012) indicated that the science of chemistry is important. For conceptual naturalness, these concepts are difficult to learn and this is in agreement with science Elemat (2006) and Johnston' study (2000) that there are difficult basic chemical concepts, just as Ma'idah's study (2008) indicated the weakness of the acquisition of scientific concepts among students at the basic stage. Science curricula are full of scientific concepts with their lack of linking between theoretical scientific concepts and their practical applications in order to sustain the learning effect. Chemistry teachers in schools face great difficulties in teaching chemical concepts.

Through the reviews by teachers, it was observed that there is a clear weakness of students to deal with chemical concepts and use thinking skills, and by looking at previous studies that dealt with the topic of thinking, it found that most of them dealt with teaching thinking in independent programs that deal with the blending of thinking skills. Going by the researcher's opinion, there is need to search for the use of learning and teaching strategies that focus on knowledge, in addition to applied skills that enhance thinking skills, transfer learning effect and develop it among students, as well as raise students to the desired level. Therefore, this study aimed to teach chemistry through the blending of both scientific and creative thinking skills according to the Schwartz model and measure the extent of their contribution to the acquisition of scientific concepts, improvement of creative thinking skills, and the transference of learning effect among ninth grade students.

The study's problem is represented by the following questions;

- What is the effect of using the Schwartz model on acquiring chemical concepts among ninth grade students?
- What is the effect of using the Schwartz model on improving the creative thinking skills of ninth grade students?
- What is the effect of using the Schwartz model in transmitting the learning effect of ninth grade students?

Methods

Research Model

The quasi-experimental approach was adopted, which included the pre and post measurement of the two groups of individuals in the experimental and control study. (scientific research book citiation)

Participants

The study population consisted of 64 students from the ninth grade, who were selected from the first elementary school of Laila Al-Ghafari, belonging to the Directorate of Education for the Marka Brigade in Amman. The other 32 female students were selected as a control group, who studied according to the traditional method.

Groups equivalence; the creative thinking skills test, the acquisition of chemical concepts test, and the learning effect test were applied to the students of the experimental and control groups, before starting the application of the study, the arithmetic averages and standard deviations were calculated for the results of the students of the two groups and it was found that there are no statistically significant differences at the level of significance ($\alpha = 0.05$) between the mean scores of the students on the tools as a whole, which means that the experimental and control groups are equivalent.

Data Collection Tools

To achieve the objectives of the study and carry out its procedures, the following study tools were prepared:

The Acquisition of Chemical Concepts Test (ACCT)

The scientific concepts acquisition test was prepared from the ninth grade basic chemistry textbook to measure the extent of chemical concepts acquisition included in the electrochemistry unit, and its results were used to reveal the effect of teaching chemistry using the Schwartz model compared to the usual method for the acquisition of chemical concepts for female students, and following the steps for preparing the concept acquisition test Chemical:

Reviewing the relevant research literature and previous studies related to its topic, analyzing the content of the (Electrochemistry) unit from the ninth grade chemistry textbook, determining the scientific concepts included in it, drafting and constructing test items to measure students' ability to acquire chemical concepts, as the test included (33) a multiple choice question with four alternatives, one of which is true. (See Appendix 1)

Test's Validity

Verifying the validity of the test content by presenting it in its initial form to a group of 19 arbitrators, including university professors specializing in science curricula and teaching methods, educational supervisors in the field of science, specialists in measurement and evaluation, and teachers who teach the subject of sciences. The test of acquiring chemical concepts, clarity of its paragraphs, and their relevance to the goal for which the test was prepared for the acquisition of chemical concepts, the linguistic integrity of the test items, and scientific accuracy, and in light of the opinions and suggestions of arbitrators, five paragraphs were deleted and five test items were added.

Test's Reliability

Verifying the stability of the test by calculating the reliability factor, using a test-retest method. The stability of the test was verified in two ways; First (test-retest); Where it was applied to an exploratory sample consisting of 30 students, and after two weeks, the test was re-applied on the same sample, and the stability coefficient (Pearson's Correlation Coefficient or Repetition Stability Coefficient) was calculated and was equal to 0.93, while the second method was by calculating the internal consistency stability factor. According to Kuder and Richardson's equation, KR-20 was equal to 0.90, and these two values are appropriate for the purposes of this study.

Time test application:

- Determining the appropriate time to answer the test items by calculating the average time taken by the first three students and the last three who submitted the test answer sheets, the appropriate time was approximately 43 minutes.
- Determination of difficulty coefficients and discrimination for the test items. The difficulty coefficient and discrimination were calculated for each of the test items, and the paragraphs with a difficulty coefficient less than 0.20 and more than 0.80 were excluded, similar to the paragraphs that had a differentiation factor less than 0.20.

The Creative Thinking Test: "Verbal Form Test (A)"

The Torrance Verbal form (A) test, modified on the Jordanian environment, was used to collect data about the level of creative thinking skills of ninth grade students. This test measures fluency, flexibility, originality and overall creative thinking, and the test consist of seven sub-tests that measure the following:

Fluency; it is the number of possible answers to a situation in a fixed unit of time.

Flexibility; it is represented by the variety of categories of possible answers to a situation in a fixed unit of time.

Originality; it is represented by the number of new and unique answers in a fixed unit of time.

These skills constitute the elements of creative thinking, and each of these seven tests requires seven minutes to answer, in addition to the time required for the instructions, (Abu Jadu, 2003).

Test's Validity

The Torrance Test for Creative Thinking has indications of validity in the Jordanian environment. Al-Shanti (1983) conducted a study in Jordan aimed at determining the indications of validity and reliability of Torrance tests for creative thinking in its modified form of the Jordanian environment. Verbal picture "A", where al-Shanti subjected the extracted data to statistical analysis, and studied the validity of the test in several aspects, namely: the validity of the criterion by calculating the correlation coefficient between the total degrees of creativity that the examined students obtained in the form of the words "A" and the scores that they obtained in the lists of their teachers 'ratings, where the correlation coefficient reached 0.70, which is a statistically significant value at the level of 0.05α.

As for internal consistency, Al-Shanti (1983) calculated the correlation coefficient between the two sub-examination scores on fluency, flexibility and originality that they obtained in each test with the total score on the single test, and the values of the correlation coefficients ranged between the scores of the two sub-subjects and the total score of the single test on the verbal form of the Torrance test. Creative thinking ranged between 0.40 - 0.75, and the dimension of fluency between 0.46 - 0.75 and the dimension of flexibility ranged between 0.40 - 0.62, while the dimension of originality ranged between 0.49 - 0.72, all of which are statistically significant. As for the values of the correlation coefficients between the scores of the subjects. The sub-categories (fluency, flexibility, and originality) that students obtained in each test, along with the total score of the creativity test, ranged between 0.37 - 0.84, and all of them were statistically significant.

In order to confirm the structural validity of the Torrance test, the verbal image (a) in this study was applied to an exploratory sample from outside the study sample consisting of 30 students from the Directorate of Education in Amman, and the Pearson correlation coefficient was calculated between the students' sub-grades (Fluency, flexibility, and originality) that they obtained in each test along with the total score for each skill of creative thinking skills, and Table 1 shows the values of these parameters.

Table 1.

Correlation Coefficients Values between the Sub-Scores of the Subjects (Fluency, Flexibility, Originality) Obtained in each Test with an Overall Score for each Element of Creativity

	First test	Second test	Third test	Fourth test	Fifth test	Seventh test
Fluency	0.65	0.71	0.75	0.74	0.63	0.64
Flexibility	0.74	0.67	0.59	0.69	0.66	0.79
Originality	0.73	0.64	0.66	0.72	0.71	0.73

It is noticed from Table 1 that the values of the correlation coefficients ranged between 0.59 - 0.79 and extended the dimension of fluency from 0.63 to 0.79, and the dimension of flexibility also extended from 0.59 to 0.79, while in the dimension of originality, it extended from 0.64 to 0.73. All are statistically significant.

Stability of the test: Al-Shanti (1983) extracted the reliability coefficient for the Torrance tests for creative thinking and used the method of retesting on a sample of 120 students, with a time difference of one week from the first application, and it was found that the reliability coefficient of the total score of the test was 0.70, while the coefficient of stability for each of the test dimensions was 0.74, 0.73, 0.38 for fluency, flexibility and originality respectively, and there are also reliability coefficients for this test applied to the Jordanian environment. The reliability factor for it in Bishara's study (2003) reached 0.83.It was 0.87 in the study of Jawarneh (2004), and 0.82 in the study of Ayasrah and Hammadna (2010).

To ensure the stability of the Torrance test, the verbal picture (a) in this study was applied to an exploratory sample from outside the study sample consisting of 30 students, and the test reliability was calculated using the Cronbach Alpha equation for the internal consistency of each of the creative thinking skills (fluency, flexibility and originality) and for the test as a whole. The test as a whole had a stability factor of (0.81), fluency (0.83), flexibility (0.72) and originality (0.70), all of which were statistically significant at the level of $\alpha = 0.05$.

The procedures for correcting the Torrance Verbal Exam (A) are as follows:

Preparation of response correction forms and transcripts for monitoring scores

The student obtains the total score of the Torrance Verbal "A" test from the total score obtained on the dimensions of fluency, flexibility and originality.

- The student obtains scores for fluency, flexibility and originality on the verbal form "A" from the total of the sub-scores for fluency, flexibility and originality that he obtains in each of the six tests for verbal "A".
- The student is given the degree of fluency according to the number of ideas on each test and the number of seven ideas, and for the degree of flexibility, it is given to the student on the basis of the number of categories of responses to which the student responded in each test, and the sub-score for originality is calculated from the total degrees of originality obtained by the student on each response, as it is given A degree of originality ranging from zero to three according to Torrance's instructions (1972: 247):

Zero: If there are no answers, or if the answers are meaningless.

- If the answers are familiar and traditional (more than 5% repeat for students).
- If the answers are somewhat unfamiliar (repeated among students (4.99% - 2%).
- If the answers are completely unfamiliar and rarely included in the answers of most students (the frequency for students is less than 2%.

Third: Test of learning transfer effect:

The researcher prepared a test for the transference of learning effect in the chemistry curriculum. The test in its initial form consisted of (11) questions, and the answer to the test was structured. For this test (18), marks were assigned. This was presented to a group of arbitrators, and after reviewing their observations, some amendments were made on some paragraphs. Accordingly, the final form of the test may consist of nine questions, each question has two marks.

The test's reliability: In order to verify the stability of the tool, internal consistency was calculated on an exploratory sample beside the study sample of 27 male and female students. The researcher aimed from the initial experimentation of the test on this sample to determine the clarity of the students' paragraphs and how they responded and determine the time required to complete the test, and analyze its paragraphs according to the equation of Coder Richardson-20 and the stability factor was 84%.

Unit Design

The unit is designed according to the Schwartz model as follows:

Defining the study unit: The unit "Electrochemistry" was chosen from the science book for the ninth grade because this unit is considered a good context for teaching thinking about the entrance to integration and achieving the two main objectives of the integration lessons, namely, teaching thinking skillfully and improving students' understanding of the content for the following reasons:

Teaching the unit takes at least 18 lessons, which gives the teacher enough time to develop thinking skills in addition to taking pre and post-tests.

The subject of electrochemistry provides the possibility of introducing creative thinking and acquiring chemical concepts, which helps in the transmission of learning effects using the Schwartz model.

The content of the study unit "Electrochemistry" has been reformulated by integrating the creative thinking skills and the acquisition of scientific concepts and the transfer of the learning effect according to the four main steps which are introduction to the content and skill of the thinking process - active thinking - thinking in thinking - applying thinking. This was arranged such that each lesson included the title of the lesson, its objectives, the creative thinking skills included, the content, activities, and evaluation methods.

Certification of the Upgraded Academic Unit

After completing the preparation of the unit in its initial form, it was presented to nine arbitrators with specialization in science curricula and teaching methods, and they were asked to express an opinion on the study unit in terms of the scientific accuracy of the content and the suitability of the chosen thinking skills for the unit and the suitability of the content for students 'age and time designated for teaching the unit, its activities and the steps for its implementation. After recovering the initial copies, they were reviewed and the necessary modifications made.

Results and Discussion

The Results related to the First Question

What is the effect of using the Schwartz model on acquiring chemical concepts among ninth grade students?

To answer this question, the arithmetic averages and standard deviations of the performance of the study individuals from the experimental group and the control group were calculated on the chemical concepts acquisition test as shown in Table 2.

Table 2.

The Arithmetic Means and Standard Deviations of the Performance of the Study Individuals on the Pre and Post Chemical Concepts Acquisition Test

Group	Number	Pre		Post	
		Mean	Standard deviation	Mean	Standard deviation
Experimental	32	12.00	3.86	26.41	2.73
Control	32	13.59	4.49	14.38	4.46
Total	64	12.80	4.23	20.39	7.09

It was observed from Table 2 that the arithmetic average of the study individuals' performance on the dimensional chemical concepts acquisition test for the experimental group that learned using a unit developed in chemistry based on the Schwartz model has reached $\bar{X}$=26.41, which is higher than the arithmetic average of the performance of the control study members, which reached $\bar{X}$=14.38.To find out whether the differences between the arithmetic averages were significant, the accompanying single analysis of variance (ANCOVA) was performed, and Table 3 shows the results of the analysis.

Table 3.

Results of an Analysis of Variance (ANCOVA) Associated with the Performance of Study Members on the Chemical Concept Acquisition Test

Source of variance	Sum of squares	Degrees of freedom	Mean of squares	Statistical value (p)	Sig	Impact size
Pre	537.437	1	537.437	105.828	0.000	
Group	2667.969	1	2667.969	525.357	0.000	0.896
Error	309.782	61	5.078			
Total	3163.234	63				

The difference is statistically significant (α=0.05)

It is noticed from Table 3 that the value of (p) for the teaching method amounted to 525,357, and a level of significance equal to (0.000), which indicates the existence of statistically significant differences between the performance averages of the two study groups on the post-chemical concepts acquisition test. The averages were also extracted and the modified arithmetic, which appears in Table 4.

Table 4.

Means and Standard Errors Adjusted for the Performance of the Study Subjects on the Post Chemical Concept Acquisition Test

Group	Number	Arithmetic average	Standard error
Experimental	32	26.97	0.40
Regularity	32	13.81	0.40

It is noticed from the previous table that the modified arithmetic mean of the experimental group that learned using a unit developed in chemistry based on Schwartz's model was $\bar{X}$=26.97, while the arithmetic average of the control group that learned by the traditional method was $\bar{X}$=13.81, This indicates that the difference was in favor of the group Empiricism, which was learned using an improved study unit in chemistry based on the Schwartz model. This confirms the effect of applying an improved study unit in chemistry based on the Schwartz model for acquiring chemical concepts among ninth grade students in Jordan compared to the traditional method.

It is evident from the results that there are statistically significant differences between the average performance of the students in the experimental and control group in favor of the experimental group and this may be attributed to the seriousness and interest in dealing with the vocabulary of the unit and the implementation of its activities, in addition to the steps of teaching the skill of thinking by incorporating it into the content. I participated in supporting meaningful learning and acquiring chemical concepts in the electrochemistry unit. The use of thinking maps in the active thinking stage helps students organize information and use it to attain a specific result. It also helped organize information. The use of brainstorming, cooperative learning and discussion provided an opportunity for students to learn and discuss. This increased their motivation to learn, acquire chemical concepts, and achieve meaningful learning, as the students were able to link new knowledge with relevant previous knowledge, which enhanced the acquisition of chemical concepts, and this is in agreement with Schwartz and Barks, (2005), and Fathallah, (2009). Using the Schwartz model fulfilled the two goals of the inclusion lessons, which were to teach thinking skillfully and improve students' understanding of content and thus, acquire chemical concepts.

The Results related to the Second Question

What is the effect of using the Schwartz model on improving the creative thinking skills of ninth grade students?

To answer this question, the arithmetic averages and standard deviations of the performance of the study members from the experimental group and the control group were calculated on the creative thinking test as shown in Table 5.

Table 5.

The Arithmetic Means and Standard Deviations of the Study's Performance on the Pre and Post Creative Thinking Test

Skill	Group	Number	Pre		Post	
			Arithmetic average	Standard deviation	Arithmetic average	Standard deviation
Fluency	**Experimental**	32	1.31	0.47	2.47	0.80
	Control	32	1.19	0.40	1.81	0.90
	Total	64	1.25	0.44	2.14	0.91
Originality	**Experimental**	32	1.41	0.56	3.44	1.34
	Control	32	1.31	0.54	1.91	1.33
	Total	64	1.36	0.55	2.67	1.53
Flexibility	**Experimental**	32	1.06	0.50	4.72	3.36
	Control	32	0.75	0.62	5.38	3.36
	Total	64	0.91	0.58	5.05	3.35
Total	**Experimental**	32	3.78	0.83	10.63	3.67
	Control	32	3.25	1.02	9.09	3.79
	Total	64	3.52	0.96	9.86	3.78

It is noticed from Table 5 that the arithmetic average of the study members' performance on the dimensional creative thinking test for the experimental group that learned using a developed unit in chemistry based on the Schwartz model reached $\bar{X}$=10.63, which is higher than the arithmetic average of the performance of the control study members, which reached $\bar{X}$=9.09, and to find out whether the differences between the arithmetic means are significant at the α=0.05 level of significance, the accompanying analysis of variance (MANCOVA) was performed, and Table 6 shows the results of the analysis.

Table 6.

Results of the Accompanying Analysis of Variance (MANCOVA) for the Performance of Study Members on the Dimensional Creative Thinking Test

Source of variation	Skill	Sum of squares	Degrees of freedom	Average of squares	Statistical value (p)	Level of significance	Impact size
Pre	**Fluency**	2.596	1	2.596	3.748	0.058	
	Originality	3.070	1	3.070	1.742	0.192	
	Flexibility	.680	1	.680	0.059	0.808	
	Total	17.541	1	17.541	1.267	0.265	
Group	**Fluency**	4.289	1	4.289	6.193	0.016	0.092
	Originality	29.081	1	29.081	16.498	0.000	0.213
	Flexibility	7.567	1	7.567	0.660	0.420	0.011
	Total	22.211	1	22.211	1.604	0.210	0.026
Error	**Fluency**	42.248	61	.693			
	Originality	107.524	61	1.763			
	Flexibility	699.288	61	11.464			
	Total	844.678	61	13.847			
Adjusted Total	**Fluency**	51.734	63				
	Originality	148.109	63				
	Flexibility	706.859	63				
	Total	899.734	63				

It was observed from Table 6 that the value of (p) for the teaching method amounted to 1.604, and a level of significance equal to 0.210, which indicates the existence of statistically significant differences between the average performance of the two study groups on the total score of the dimensional creative thinking test, as well as the absence of differences in the skill of flexibility. There were differences in the skills of fluency and originality, as the value of q ranged between 16.498 - 6.193, with a level of significance between 0.000 - 0.016, and the modified arithmetic averages were extracted for the skills of fluency and originality, which appear in Table 7.

Table 7.

Mean and Standard Errors Adjusted for the Performance of Study Subjects on the Two Skills of Fluency and Dimensional Originality

Skill	Group	Number	Modified	
			Mean	Standard error
Fluency	**Experimental**	32	2.41	0.15
	Control	32	1.87	0.15
Originality	**Experimental**	32	3.37	0.24
	Control	32	1.97	0.24

It was observed from the previous table that the modified arithmetic mean of the experimental group that learned using a developed study unit in chemistry based on the Schwartz model in the skill of fluency reached $\bar{X}$=2.41, while the arithmetic average of the control group that learned using the traditional method was $\bar{X}$=1.87, and the modified arithmetic mean was for the experimental group that learned using a developed study unit in chemistry based on the Schwartz model in the skill of originality $\bar{X}$=3.37, while the arithmetic mean of the control group that learned by the traditional method was $\bar{X}$=1.97 and this indicates that the difference was in favor of the experimental group that learned using an improved study unit in chemistry based on the Schwartz model. There was improvement on the skills of fluency and originality among ninth grade students in Jordan that used the Schwartz model compared to the traditional method.

The results of this question showed that there are statistically significant differences between the average performance of the students in the experimental group and the control in favor of the experimental group. This method uses the main principles of teaching thinking, which is that the more clearly the teaching of thinking, the greater its impact on the students, and they achieve a better way of thinking. Thinking and content, and whenever the developed unit contributed to achieving these principles for students, and reformulating the unit by clearly displaying the skill of thinking, then the content are displayed and the skill of thinking applied to the content for each lesson, which enable the student to understand the two matters together and the ability to connect between them. Inclusion teaching steps in the Schwartz model contribute to enhancing students' ability to think creatively and provide an opportunity for students to discuss, exchange and evaluate their ideas to obtain results at the end of each activity.

This result can also be attributed to the Schwartz model, which played a major and important role in developing creative thinking through the steps it is based on, as it relies on the gradual transition of the student towards the correct answer and the interpretation and criticism of each answer to make it easier for the student to correct mistakes and arrive at the concept.

It also works on analyzing knowledge into its dimensions and linking previous knowledge with the new, which means motivating students, thinking with extreme precision, using analysis and extracting results, and linking the apparent reasons together to reach the common reasons. This needs fluency and flexibility on the part of the students through the use of discussions and coming out with unfamiliar results, and these are creative thinking skills.

The Results related to the Third Question

What is the effect of using the Schwartz model in transmitting the learning effect of ninth grade students?

To answer this question, the arithmetic means and standard deviations of the performance of the study from the experimental and control group were calculated on the transference of learning effect test, as shown in Table 8.

Table 8.

Arithmetic Means and Standard Deviations of the Performance of Study Individuals on the Transmission of the Effect of Pre and Post-Learning

Group	Number	Pre		Post	
		Mean	Standard deviation	Mean	Standard deviation
Experimental	32	2.16	1.25	8.16	1.87
Regularity	32	2.44	1.39	4.59	1.01
Total	64	2.30	1.32	6.38	2.33

It was observed from Table 8 that the arithmetic mean of the study individuals' performance on the dimensional transference of learning effect, for the experimental group that learned using a study unit developed in chemistry based on the Schwartz model $\bar{X}$=8.16, which is higher than the arithmetic average of the performance of the control members, which reached $\bar{X}$=4.59, and in order to find out whether the differences between the arithmetic means are significant at $\alpha = 0.05$level of significance, the accompanying single analysis of variance (ANCOVA) was performed, and Table 9 shows the results of the analysis.

Table 9.

The Results of the Accompanying One-Way Analysis of Variance (ANCOVA) of the Performance of Study Individuals on the Transmission of the Effect of Distant Learning

Source of variance	Sum of squares	Df	Mean of squares	"F" value	Sig	Impact size
Pretest	0.155	1	0.155	0.068	0.796	
Group	199.514	1	199.514	87.066	0.000	**0.588**
ERROR	139.782	61	2.292			
Total	**343**	**63**				

* *The difference is statistically significant*

It was observed from Table 9 that the value of (q) for the teaching method reached (87,066), and a level of significance equal to (0.000), which indicates the existence of statistically significant differences between the performance averages of the two groups on the dimensional transference of learning effect test. The modified arithmetic means appear in the following Table 10.

Table 10.

The Mean and Standard Errors Adjusted for the Performance of Study Individuals on the Transmission of the Effect of Distant Learning

Group	N	Mean	Standard error
Experimental	32	8.15	0.27
Control	32	4.60	0.27

It is noticed from the previous Table 10 that the modified arithmetic mean of the experimental group that learned using a unit developed in chemistry based on Schwartz's model reached $\bar{X}$=8.15, while the arithmetic average of the control group that learned by the traditional method reached $\bar{X}$=4.60, and this indicates that the difference was in favor of the experimental group that learned using an improved study unit in chemistry based on the Schwartz model. This confirms the effect of applying an improved study unit in chemistry based on the Schwartz model on the transference of learning effect among ninth grade students in Jordan compared to the traditional method.

The accompanying analysis of variance ANCOVA showed that there are statistically significant differences at the level of $\alpha = 0.05$ between the averages of students' performance on the transmission of the learning effect test and for the benefit of the experimental group that studied according to the Schwartz model. The teaching is clearer, and the classroom environment is characterized by the work of the mind and active thinking, and the more the merging between thinking and the content of the lesson, the more students think about the content of the lesson and increase the comprehension. In addition, the final stage of this model is in linking previous learning with current learning, applying thinking in new situations and helping students to transfer the skill of thinking in their daily lives and the situations they face, through exercises of near and long transmission of the impact of the training, which provides the opportunity for students to summarize what they have learned and link it to his knowledge. This increases his ability to employ new knowledge in daily life situations, and this means the transmission of the learning effect.

Recommendations

In light of the results, the study recommends:

- Science teachers should include skills for teaching creative thinking in their science teaching; because of their effectiveness in acquiring chemical concepts and developing creative thinking skills among students.
- There is need for educational supervisors to hold training courses and workshops for science teachers in order to train them on how to use the Schwartz model and integrate thinking skills into content. Also, to urge them to use it in teaching through individual meetings and publications.

- The need to include contexts of creative thinking and the impact of learning according to the Schwartz model, by integrating creative thinking skills and life skills to transfer the impact of learning, through an explicit and clear integration of thinking skills in the academic curriculum. It is to be used in the teaching process, and to provide a guide for the teacher, explaining how to employ each of them in the science teaching process by those in charge of designing and writing science curricula in the Ministry of Education. Science books should be used for this stage.

Suggestion to researchers: Conducting similar studies to reveal the effectiveness of the Schwartz model in teaching science and teaching thinking skills - especially in which Arab studies are few - in developing other aspects of learning, such as different higher thinking styles, or science processes, and in teaching students' courses in stages. It is suitable also for other categories of students, such as high school, and in teaching students of different levels, such as gifted students.

Limitations of Study

Human borders: it is limited to a sample of ninth grade students. Spatial boundaries: It was conducted in a school belonging to the Directorate of Education in Amman. Time limits: conducted in the 2018/2019 academic year.

Generalizations are defined by the following limitations in this study: This study dealt with the electrochemistry unit in chemistry for the ninth grade, developed and based on integrating creative thinking skills into content according to Schwartz model. The scientific concepts test, the verbal Torrance test (A) for creative thinking, and the learning effect survival test, being the results of this study were determined in light of the validity and reliability of the tools and the degree of interest and objectivity of students in answering them.

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Appendix 1.

The Acquisition of Chemical Concepts Test (ACCT)

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1- The anode in the galvanic cell is the electrode:

A) The negative at which the oxidation process occurs
B) The negative at which the reduction process occurs.
C) The positive at which the oxidation process occurs
D) The positive at which the reduction process occurs

2- The following reaction represents a galvanic cell: Zn + Ni $^{+2}$ → Zn $^{+2}$ + Ni, the zinc is considered:

A) Anode with positive charge B) Anode with a negative charge
C) Cathode with positive charge D) Cathode with negative charge

3- If you know that the following reactions I spontaneous reaction:
Fe $^{+3}$ + Cu → Cu + 2 + Fe $^{+2}$
Cu $^{+2}$ + Cd → Cd $^{+2}$ + Cu
The arrangement of substances according to their strength as reducing agents is:

A) Cd > Fe $^{+2}$> Cu B) Cu $^{+2}$> Cd $^{+2}$> Fe $^{+2}$
C) Fe $^{+2}$> Cu $^{+2}$> Cd $^{+2}$ D) Cd > Cu > Fe $^{+2}$

4– If the zinc reduction voltage (- 0.76 V) and the nickel reduction voltage (- 0.25 V) then the E® of the next galvanic cell is equal to Zn + Ni + 2 → Zn + 2 + Ni in volts

A) -0.51 B) +0.51 C) - 1.01 D) + 1.01

5- A galvanic cell was formed with its electrodes of silver and hydrogen. It was found that E® of the cell = 0.8 volts. If you know that the silver electrode is the positive electrode in the cell, then the reduction potential of silver is

A) -0.8 B) +0.8 C) 1.8 D) 8.1

6- A student prepare a galvanic cell, one of its electrodes of silver and the other of magnesium, the value of E0 of the cell is in volts in standard conditions it is equal to:

A) 3.17 B) 2.37 C) 1.57 D) 0.80

7- When a copper wire and a silver wire are placed in a dilute solution of HCl:

A) Only the silver wire reacts with the acid B) Only the copper wire reacts with the acid
C) The silver and copper wires react with the acid D) Neither wire will react with the acid

8- A substance whose hydrogen gas cannot be produced when electrolyzing its aqueous solution with graphite electrodes is:

A) $CuSO_4$ B) H_2SO_4 C) NaBr D) $MgCl_2$

9- The voltage of the galvanic cell E^0 consisting of two electrodes of magnesium and lead in volts is equal to:
A) 2.50 B) 2.42 C) 2.24 D) 2.37

10- Using electrolysis, the following operations can be performed, except:

A) Coating a spoonful of iron with a plate of nickel
B) Extraction of sodium from its compounds
C) Preparation of sodium chloride from sodium hydroxide solution
D) Purification of lead from impurities

11- When electrolysis of KBr solution, the reaction that takes place at an anode is:
A) $H2O + 2e^- \rightarrow H2 + 2 OH-$
B) $2 Br^- \rightarrow Br_2 + 2e^-$
C) $2 K^+ + 2e^- \rightarrow 2 K$
D) $2 H_2O \rightarrow O_2 + 4 H^+ + 4e$

12- When coating an iron coin with a layer of nickel, half of the reaction-taking place on the anode is in the solution cell Nickel chloride is:

A) $Ni^{2+} + 2e^- \rightarrow Ni$
B) $Ni \rightarrow Ni^{2+} + 2e-$
C) $Fe^{3+} \rightarrow 3e- + Fe$
D) $Fe \rightarrow Fe^{2+} + 2e$

13-The electrolysis of a Na_2SO_4 solution between graphite electrodes, the material that reduces at the cathode is:

A) Sodium cations B) Sodium atoms C) Sulfate anions D) Water molecules

14- When electrolysis of a KI solution using graphite electrodes, the products of the electrolysis are:
A) Iodine and oxygen B) Iodine, oxygen and potassium hydroxide
C) Iodine and hydrogen D) Iodine, hydrogen and potassium hydroxide

15- When electrolysis of a $CuSO_4$ solution with graphite electrodes, a cathode is produced:

A) Copper atoms B) Hydrogen gas C) Sulfur D) Oxygen gas

16- The balanced reaction that occurs automatically is:

A) $Pb^{2+} + 2Ag \rightarrow 2Ag^{+} + Pb$
B) $Ag^{+} + Pb \rightarrow Ag + Pb^{2+}$
C) $Pb^{2+} + Ag \rightarrow Ag^{+} + Pb$
D) $2Ag^{+} + Pb \rightarrow 2Ag + Pb^{2+}$

17- The reaction that takes place on an Anode upon electrolysis of a KI solution between graphite electrodes is:

A) Oxidation of iodide anions B) Reduction of potassium cations
C) Oxidation of water molecules D) Reduction of water molecules

18- One of the following metals reacts spontaneously with a solution containing Cr^{3+} ions but not with a solution containing Ca^{2+} ions:

A) Nickel B) Magnesium C) Lead D) Tin

19- One of the following metals can be prepared by electrolysis of a solution of one of its compounds:

A) Aluminum B) Magnesium C) Nickel D) Potassium

20- The Cathode of the galvanic cell is always:

A) The cathode and a reduction process occur
B) The anode and an oxidation process
C) The negative electrode and it has an oxidation process
D) The anode and a reduction process

21- The metal that can be used as a container to store the chromium sulfate solution and it is not possible to use a spoonful of it to stir the nickel sulfate solution is:

A) Aluminum B) Silver C) Iron D) Zinc

22- One of the following metals cannot be prepared by electrolysis of a solution of one of its salts:

A) Magnesium B) Lead C) Gold D) Chromium

23-That is the following statements are incorrect for electrolyte cells:

A) The cathode is the negative electrode
B) The oxidation process occurs at the anode
C) Their interactions do not occur spontaneously
D) The reaction potential (E^0) has a positive value

24- When passing an electric current in a solution of an unknown substance using platinum electrodes, hydrogen gas rose at the cathode and Oxygen gas in an anode, the substance could be:

A) $AgNO_3$ B) $CuSO_4$ C) KBr D) NaOH

25- The number of moles of copper deposited at the cathode in the electrolysis process of a $CuSO_4$ solution at 9650 C of electricity is equal to:

A) 0.1 B) 0.05 C) 0.2 D) 0.5

26- In a dry zinc-carbon cell, oxidation occurs:

A) Zinc at the anode B) Zinc at the cathode C) Manganese at the anode D) Manganese at the Cathode

27- When a rechargeable cell produces electrical energy it works:

A) Electrochemical cell B) Electrolytic cell C) Voltage cell D) Half cell

28- In the following galvanic cell: Zn / Zn + 2 // Cu / Cu + 2 the following occurs:

A) Oxidation of the copper electrode B) Reduction of the zinc electrode
C) Reduction of the copper cation D) Reduction of the zinc cation

29- When electrolyzing an aqueous solution of ($CuSO_4$) using graphite electrodes, it

A) The copper atoms are oxidized on the anode
B) Hydrogen gas evaporates at the helipad
C) The oxygen gas rises at the Anode
D) Sulfur is formed at the cathode

30- When analyzing a mixture of two solutions ($MgSO_4$, $CuSO_4$), half of the expected reaction on the negative electrode

A) $Mg^{+2} + 2e^{-} \rightarrow Mg$
B) $2H_2O + 2e^{-} \rightarrow H_2 + 2OH^{-}$
C) $Cu^{+2} + 2e^{-} \rightarrow Cu$
D) $2H_2O \rightarrow 4H^{+} + O_2 + 4e^{-}$

31- When electrolysis of a KI aqueous solution of potassium iodide using graphite electrodes, what happens on the cathode is:

A) Iodine deposition
B) Potassium deposition
C) An acidic medium is formed

D) Release of hydrogen gas

32- If the lithium hydride melt (LiH) is electrolyzed using platinum electrodes, the anode reaction is

A) $Li \rightarrow Li^{+} + e^{-}$
B) $2H^{+} + 2e^{-} \rightarrow H_2$
C) $2H^{-} \rightarrow H_2 + 2e^{-}$
D) $2H_2O \rightarrow 4H^{+} + O_2 + 4e^{-}$

33- The metal M dissolves in a 1 mol / liter hydrochloric acid (HCl) solution and H2 is released, while it does not dissolve in the FeSO4 solution. (Iron reduction voltage --0.44 volts), one of the following values represents the potential reduction potential of the metal.

A) 0.14 Volt
B) -0.25 Volt
C) -0.56 Volt
D) -0.72 Volt