Developing Chemistry Curriculum of Secondary Stage in the light of (STEM) Approach

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ABSTRACT

The present study aimed at developing the chemistry curriculum of the secondary stage at Saudi Arabia Kingdom in the light of STEM Approach. To achieve this aim, a list of the criteria that should be presented in the secondary stage, chemistry curriculum in light of STEM Approach was prepared. Content analysis of the curriculum was done. This analysis showed failure in the present chemistry curriculum represented in the Geometric design criteria, the integration of STEM criteria, the objectives, activities, content, strategies, material, instruments, technological equipment, and evaluation means as they should be there in the STEM Approach. According to these findings, a perspective to develop the chemistry curriculum of the secondary stage in the light of STEM Approach was suggested. Therefore, two units (electro chemistry) and (bio-organic compounds) were selected and applied on a sample of third year secondary stage students to detect to what extent they are effective in developing higher thinking skills and creative thinking skills. A sample of (72) students were divided into an experimental group (36) students who studied the developed units and a control group (36) students who followed the traditional method. Instruments of the study were a test in higher order thinking skills that measured (analysis, synthesis, and *evaluation), and another test in the creative thinking skills to measure levels of (fluency, flexibility, and originality). Application of the pre-post tests on both groups showed a statistical significant difference at 0.05 level between means of scores of the experimental and control group students in the post test application and a statistical significant difference at 0.05 level between means of scores of the control group students in the pre and post application of the higher order thinking skills test as a whole and in each individual skill in favor of the post application. There was also a statistical significant difference at 0.05 level between means of scores of the two groups in the post application of the creative thinking test as a whole and in each individual skill in favor of the experimental group There was also a statistical significant increase and strong correlation at 0.05 level of significance between means of scores of the experimental group on the post application of the higher order thinking skills test and their scores on the post application of the creative thinking test. This means that when students' scores increased in the higher thinking skills test, their level in creative thinking increased*

Key words: STEM Approach- Secondary school chemistry curriculum- Saudi Arabia Kingdom

Introduction

Ministry of Education at Saudi Arabia Kingdom aims to develop second school curricula to cope with the scientific technological advancements of the industrial countries. The most important aim of this development is to prepare students who can compete in the work market. Schools of the secondary stage aim at offering a kind of education that can prepare students to join the university level after getting enough amount of the basic skills of applied sciences. They also aim at providing students with high experience based on scientific information that can help them solve their daily problems. One of the urgent challenges that faces quality of science education outputs recently is memorizing and neglecting the mental abilities of students, such as thinking skills, problem solving, decision taking, analysis, deduction, criticism, low benefit from instructions and recent theories in teaching the natural sciences (chemistry, physics, biology), building and organizing school curriculum and designing the learning material. Besides, the low education outputs in science when compared to many advanced and developing countries. This is clear in both local and international studies and in in the findings of the international instructions in mathematics, and science (TIMSS) In 2003 (Rafie,AL Oishek, 2011:114).

However, when revising the secondary stage curriculum in Saudi Arabia, it was evident that these curricula were designed according to the separate subjects curricula and are based mainly on the achievement of experiences and information. This assures that the subject matters that are taught in the governmental and private schools in Saudi Arabia in this stage contain separate subjects, chemistry, physics, biology, geology, mathematics, computer, each of which is taught separately from the others (Mohamadi,2018:124).

Chemistry is considered one of the natural sciences described as the central science of all specializations such as: medicine, and pharmacy. It has many contributions in the fields of industry and medicine. This motivates the world countries to build programs to shed light on its importance and its role in serving the society. (El Ghamedi: 2012).

When looking at the present chemistry curricula of the secondary stage , we found it far from providing students with the basic skills of scientific thinking, critical thinking, creative thinking, and problem solving, etc. They also concentrate on achievement through mimicry memorization and neglect the higher order thinking skills such as analysis, synthesis, and evaluation. They are also unrelated to the technological advancements in teaching aids and in the engineering designs on which the scientific problems depend to solve problems and take decisions that help students of the secondary stage and prepare them for the university level and the requirements of the work field. For example, the engineering designs are unrelated to the technological advancements in all fields of knowledge. This leads to neglecting the application of recent trends in curricula design which are based on the integration of sciences, technology, engineering designs and mathematics, (Ghanem (2015:6)

STEM Approach is one of the curricula that integrates science, mathematics, technology, and engineering. It is considered one of the world practices in designing school curricula. It is an acronym of the first letters of the school subjects (science, technology, engineering and math) The nature of this curriculum requires a learning environment to help students be enjoyed during practicing activities and learning projects which consequently enable them to get comprehensive and integrated knowledge using the scientific approach in thinking, away from the traditional instruction used in the classroom , (Al Mohesen and Khaga,2015:50) and Murad, 2014:18)

STEM Approach has a group of basic rules when designing curriculum (Ghanem .2013:54), (Saied, Al Gharky, 2015:140) including a group of activities and class practices that happen inside the learning environment such as:

- Integrating subjects and curricula through learning activities that integrate science, engineering, technology, and mathematics.
- Designing projects, and creating a new environment. This is called quadrilateral integration (content, processes, outcomes, and environment).
- Creating a creative output by using the environmental materials. In project based learning, the students design practical and creative projects when working cooperatively in groups, learning through models based on the integration of STEM.
- The learning activities presented in STEM Approach will vary according to the set objectives.
- Studying and applying the process of engineering design: the curriculum is based on the engineering design to solve the real problems and use mathematics skills and algorithms to recognize the rules of the design branches. It also includes relating school teaching with the actual experiences and technology production.
- Education consolidation through using technological potentials and computer programs. Curriculum developed according to STEM Approach depends on electronic learning whether asynchronous or synchronous.
- Evaluating students using real and comprehensive assessment tools: STEM Approach is based on evaluating the instruments, the design and the real solutions of each problem in the curriculum.
- Relating student to his environment and the local community: this requires strengthening the training

objectives and the research work related to the society to connect the student to his environment and his local community.

- STEM Approach is based on the intermediate curriculum and uses designs focusing on the learner and on the real problems identified with the objective of imposing them on the learners and including different subjects such as engineering, science, math, and technology.

Some previous studies aimed at developing science curriculum in the light of STEM Approach (El Baz, 2017), Al Dorry (2018), Mohamed (2018), Awad & Barak(2018), Shoera (2020). These studies indicated the effectiveness of this developed curriculum in the light of STEM Approach in some variables such as school achievement, critical thinking skills, mind habits and induction.

While other studies aimed at preparing a curriculum or a program or a suggested unit or enrichment activities according to STEM (Ahmed, 2006), Abd El Fattah (2016), El Essawy (2016), Ismael (2017), Hagag (2018), Al Galal (2018), Al shenawy (2019), Al GHamedi & Hussein (2019). These studies proved the effectiveness of the program or the suggested unit in developing some cognitive skills and in affecting learning outputs.

Many studies showed the effect of STEM Approach on achieving many objectives of teaching the natural sciences such as thinking and attitudes towards the subject, and on the acquisition of concepts, and problem solving such as the study of Murad (2014), Al Shahima (2015)m and Al Mohamadi (2018) The suggested perspective of the developed curriculum includes concepts, skills, applications, technology, engineering, and mathematics. It also presents curriculum topics through the integration of the four subjects, focusing on the problems, and designing science computer programs. The curriculum uses the process of engineering design to solve the big problems of the community using instruments from the surrounding environment, It also presents a group of activities based on research and inquiry to help provoke thinking and creation and present suitable learning sources. Carrying out the design and validating it depends on contacting experts in the field of industry, production and experimentation through workshops, and labs prepared especially for this purpose. Learning is based on projects, assessing performance and self-evaluation.

STEM Approach depends on instructional curriculum which is mainly based on projects to give learners the chance to share in posing a problem and solving it, taking the suitable decisions to help in shifting from the traditional instruction that concentrates on mimicry memorization, to providing students with thinking skills, to instruction that depends on developing the students' thinking skills and helps in increasing the attitudes towards learning chemistry and increases their motivation to create and discover. It also includes practices and manual activities, group work and presentation of products (Barak,2014), Zaid, (2014)

Context of the problem

Failure of chemistry curriculum of the secondary stage in particular and science in general to integrate science, technology, engineering, and math (STEM) , failure to include the basic skills of science and math to help in developing the higher order thinking skills, the creative thinking and inquiry (AlDorry 2018), (Ghanem, 2015), besides the absence of formal regular instruction to teach STEM in the Kingdom until now and gaps in teaching STEM in both high and intermediate levels, El Dosary (2015).

To encounter the problem of this study represented in the failure of the chemistry curriculum in the secondary stage at Saudi Arab Kingdom in presenting scientific concepts and relating them to technology, engineering, and mathematics and dealing with topics separately, it was found that it loses the integrating characteristic among different subjects. To solve this problem, the present study tried to answer the following questions:

- What are the criteria that should be available in chemistry curriculum according to STEM?
- What is the extent of finding these criteria in the present chemistry curriculum?
- What are the basics of the suggested perspective for developing the chemistry curriculum according to STEM Approach?
- What is the suggested perspective for developing chemistry curriculum according to STEM Approach?
- What is the effect of the suggested unit in the suggested perspective for developing chemistry curriculum at Saudi Arabia kingdom in the light of STEM Approach for developing higher order thinking skills and creative thinking skills of third year secondary school?
- What is the type of correlation between higher order thinking skills and creative thinking skills of third year secondary school students?

Aims of the study:

- Developing chemistry curriculum of the secondary stage in light of STEM Approach.
- Identifying the effect of a suggested unit from the perspective of developing chemistry curriculum of the secondary stage at Saudi Arabia in light of STEM Approach on promoting the higher order thinking skills of third year secondary school students.
- Identifying the effect of a suggested unit in the perspective on developing chemistry curriculum of the secondary stage at Saudi Arabia in light of STEM Approach on promoting the creative thinking skills of third year secondary school students.

Delimitations:

The study was delimited to

- developing chemistry curriculum of the secondary stage in light of STEM Approach for first, second, and third years (students' book).
- teaching two units of the suggested curriculum in light of STEM Approach to third year students' textbook (electro chemistry , and bio-organic compounds)
- a group from third year secondary school students at Saudi Arabia kingdom , Al kharg governorate (an experimental group learning the two units developed in light of STEM Approach, and a control group learning by the traditional method (72 students).
- higher order thinking skills (analysis, synthesis, and originality).
- creative thinking skills (fluency, flexibility, and originality)

Instruments and material-

- checklist of the chemistry curricula of third year secondary stage in light of the list of criteria assigned for STEM Approach.(prepared by the researchers).
- test in higher order thinking skills in chemistry of third year secondary.(prepared by the researchers)
- test in creative thinking skills in chemistry of third year secondary.(Torrance test)
- The suggested perspective of developing chemistry curriculum of the secondary stage in light of STEM Approach.
- teacher's guide book for teaching a suggested unit in chemistry curriculum developed according to STEM Approach.
- students' book for teaching a suggested unit in chemistry curriculum developed according to STEM Approach.

The Experimental Design

The study used the following designs

- The descriptive design to analyze the chemistry curriculum of the secondary stage (first, second, and third years) in both first and second semesters.
- The experimental design: two groups were used, one experimental group who was taught the two developed units and a control group who was taught according to the regular method.

The study included an independent variable represented in the suggested unit itresented in the suggestednt ht by the the first and regular method.who were taught the two units second semestersin the perspective of developing chemistry according to STEM Approach, and two dependent variables: higher order thinking skills and creative thinking skills.

Significance of the study

The study is significant in:

- Directing curriculum chemistry designers to the significance of integrating sciences, engineering, math, technology and their applications in the field of engineering and science to develop thinking skills. This might help in identifying dimensions of curriculum design for the gifted according to STEM Approach.
- Directing curriculum chemistry teachers towards using methods of teaching and strategies that depend on merging learning by projects, deduction, and scientific thinking in light of STEM Approach to develop thinking skills in chemistry.
- presening a student's book in the units (electro chemistry and chemistry of bio-organic compounds that might benefit learners through the integrated activities and the engineering designs in understanding the big topics in the integration, and developing research skills and inquiry.
- Refining students' skills and experiences through group work and the engineering design and solving problems that they encounter to be able to cope with the current age developments, and to develop third year secondary school students' creative thinking.

Definitions of study terms

- STEM Approach: (the operational definition): A group of experiences and practical practices that students of the secondary stage do with the aim of integrating science, technology, engineering and math through using a group of scientific inquiry methods and activities concentrating on the learner and depending on the scientific projects, the engineering designs and problem solving that might face secondary school students when studying the two units of chemistry.

- The higher order thinking skills: (The operational definition): The high mental processes that the present research sought to include in the chemistry curriculum of third year secondary in light of STEM Approach through the high levels of thinking in Bloom's taxonomy (analysis, synthesis, and evaluation). This will be determined through the student's scores on the higher thinking skills test.
- Creative thinking (The operational definition) It is a cognitive process in which the student's mind is activated in the two units of (electro chemistry and bio-organic compounds) with the aim of reaching to something new. This includes producing new and unfamiliar ideas and looking at things differently with the aim of reaching to solutions to problems and learning situations that might be encountered in fluency, flexibility and originality.

Procedure of the study:

First: preparing a list of criteria that the chemistry curriculum should include in light of STEM Approach to answer the first question of the study/;' what are the criteria that should be available in the chemistry curriculum in light of STEM approach?

The study extracted a group of dimensions that represent the criteria in light of STEM amongst which are:

- Integrated STEM
- Engineering design
- Objectives of the curriculum in light of STEM APPROACH
- Content of the curriculum in light of STEM APPROACH
- Materials and tools
- Evaluation methods

Second: analyzing content of chemistry curriculum of the secondary stage in light of the criteria that should be included in chemistry curriculum according to STEM Approach

To answer the second question of the study " What is the extent of the available criteria in the present chemistry curriculum?

After preparing the a list of criteria in light of STEM Approach, it was involved in the checklist of content analysis of chemistry curriculum (Appendix 2). The checklist went through the following steps

Identifying the objective of the content analysis tool-1
The aim of analyzing the content of chemistry curriculum of secondary stage students was as follows:

- identifying to what extent the criteria of STEM were represented in chemistry curriculum and evaluating it.
- Building the suggested perspective to develop chemistry curriculum in light of STEM Approach
- Designing the suggested unit in light of STEM Approch for developing the higher order thinking skills and the creative thinking skills of third year secondary stage students.

2- designing the analysis tool

An analysis checklist was prepared in light of the criteria of the chemistry curriculum based on STEM Approach (first, second, and third year secondary stages syllabi)

3- identifying dimensions of analysis:

The analysis checklist consisted of seven (7) criteria represented in the basic dimensions under which a group of sub indicators numbered (84) was involved. The following table shows the dimensions of the analysis.

Table (1): The basic criteria in light of STEM Approach and the sub indicators of each criteria

No.	Basic criteria	Sub indicators
1	**Objectives of STEM based curriculum**	**20**
2	**STEM integration**	**14**
3	**Engineering design**	**11**
4	**STEM Based activities and learning strategies**	**14**
5	**Curriculum content**	**12**
6	**Material and tools**	**7**
7	**Evaluation tools**	**6**
	total	**84**

4- determining the sample of analysis

all topics of chemistry books prescribed for the secondary stage (chemistry 1, chemistry 2, and chemistry 3) for first, second, and third years secondary school at Saudi Arabia Kingdom

5- determining the unit to be analyzed

The analyzed unit was represented in the topics of the chemistry curriculum of first, second, and third years secondary stage.

6- analysis rules

- During analysis of (chemistry 1, chemistry 2, and chemistry 3) the researcher was committed to the following:

- Comprehensive analysis of all topics in chemistry curriculum for secondary stage students (chemistry 1, chemistry 2, chemistry 3, and chemistry 4) including pictures and diagrams.
- recording frequencies. A separate form was allotted for each grade. Frequencies were used to record the emergence of each dimension: the use range (used- not used) the shape of the usage (explicit- implicit) and (detailed-brief) levels in the chemistry curriculum for the secondary stage.

controlling the analysis tool:

To ensure the validity of the analysis tool and to know its strength to represent the content needed to be analyzed and measured, the tool was submitted to a group of specialized jury members in (methods of teaching) to judge the suitability of the tool to analyze the content of chemistry curriculum for students of first, second, and third year secondary stage and judge to what extent the tool contains criteria of STEM Approach and to what extent it is scientifically safe and linguistically accurate. Their most important comments are : reducing the number of indicators of the work group, material and learning tools. Others prefer omitting the criteria of the work group as it is far from the basics of the curriculum, and rephrasing indicators of objectives of the curriculum in light of STEM Approach. Still others require including operational examples before the indicators. Jury member's comments were taken into consideration by coordinating with the supervisory committee.

Reliability of the analysis tool

To ensure the reliability of the tool the study followed the following steps:

- Emphasizing the tool's reliability by the individuals who did the analysis, the researcher analyzed the tool along with another teacher of chemistry. They did the analysis after agreeing on the main basics of analysis. Then, they met to define points of agreement and points of differences
- analysing the content twice with two weeks interval to ensure content reliability.
- using Holesty's formula to count the internal consistency. It was evident that internal consistency between the two times of analysis was (88%) . This indicates that reliability of analysis is high.

Third : Basics of the suggested perspective for developing the chemistry curriculum in light of STEM, Approach

To answer the third question: what are the basics of the suggested perspective for developing the chemistry curriculum in light of STEM Approach, the researcher carried out the analytic descriptive study according to STEM Approach and the previous studies and limited them to a group of dimensions as follows

- The philosophy of science curriculum in the secondary stage
- The distinguished traits of STEM. Learning
- Recent developments in science and technology.
- Merging between scientific inquiry and technology.
- Using the engineering design to solve problems
- Integrating the branches of STEM.
- Communicating.
- Working on projects and problems related to the real world and the environment around.

- Considering the characteristics of secondary stage students.
- Considering the applicability of the suggested perspective.

Fourth: The suggested perspective for developing chemistry curriculum in light of STEM Approach

To answer the fourth research question : what is the suggested perspective for developing the chemistry curriculum in light of STEM Approach? The following procedures were followed

1- Requirements of the suggested perspective in light of STEM Approach

- A list of the criteria of the future science generation (NGSS) prepared in light of the criteria document issued from the national research center in America (NRC)
- results of evaluating the chemistry curriculum in light of STEM Approach for students in the secondary stage.
- problems that face the Saudi community and the characteristics of secondary stage students

2-Objectives of the suggested perspective for developing the chemistry curriculum in light of STEM Approach (learning outcomes)

- The content of the suggested perspective in light of STEM
- Activities and teaching aids
- Great challenges
- Being certain of the accuracy of the suggested perspective.
- Applying the suggested perspective for developing the chemistry curriculum of secondary stage students in light of STEM Approach

The following table shows the suggested time plan for developing chemistry curriculum in light of STEM Approach for secondary stage students

Table (2) the suggested time plan of developing chemistry curriculum in light of STEM Approach for secondary stage students

class	chapter	No. of lessons	No. of periods	Class	chapter	No. of lesson	No. of periods
First year chemistry curriculum (1)	Introduction to chemistry	4	12	Second year chemistry (2)	Electronics in atoms	3	12
	Material properties & changes	4	12		Periodic table	3	10
	Atom structure	4	12		Ionic compounds & metals	4	12
	Chemical reactions	3	20		Covalent compounds	5	18
	mall	5	20		Chemical calculations	4	12
Third year chemistry (3)	States of matter	4	16		hydrocarbon	5	18
	Power &chemical changes	4	14	Third year chemistry (4)	gases	3	12
	Speed of chemical reactions	3	12		Mixtures & solutions	4	16
	Chemical balance	3	15		Acids and bases	4	14
	Derivatives of hydrocarbons	5	20		Oxidation& reduction reactions	2	8
	---------	--	---		electrochemistry	3	14
					Bioorganic compounds	4	16
No. of all lessons			83	No. of all classes			315

The suggested perspective of the developed curriculum contains a vision for developing the chemistry curriculum of the secondary stage as follows:

- First: the suggested perspective for developing chemistry curriculum of first year secondary stage (chemistry 1) in light of STEM Approach . Appendix (3)
- Second: the suggested perspective for developing chemistry curriculum of second year secondary stage (chemistry 2) in light of STEM Approach . Appendix (4)
- Third: the suggested perspective for developing chemistry curriculum of third year secondary stage (chemistry3) in light of STEM Approach . Appendix (5)
- Fourth: the suggested perspective for developing chemistry curriculum of third year secondary (chemistry 4) in light of STEM Approach . Appendix (6)

Fifth : the suggested perspective for developing a unit in chemistry curriculum of third year secondary stage in light of STEM Approach .

The Form of the suggested unit for developing the high order thinking skills and the creative thinking skills of third year secondary.

A group of procedures were undertaken as follows:

- Choosing a unit from the developed curriculum (Appendix 7).
- Finding the relative weight of the experimented unit and why it was chosen
- Preparing the two experimented units (student's book)
- Preparing the teacher's guide
- Preparing a portfolio of the unit and its project
- Preparing the two tools (a test in higher order thinking skills and the creative thinking skills test)

Following is a description of each part of these procedures

1-Choosing a unit from the developed curriculum

Two electro-chemical unit and bioorganic compounds units are chosen from chemistry book 4 for third year students and the two units were developed in light of STEM Approach

2- Finding the relative weight of the experimental unit and why it was chosen

These units represent one third of the second semester taken from six chapters in the chemistry curriculum (book 4). The number of classes required for teaching the two units amounted to 25 periods. These two units were chosen for the following reasons:

- The two units include many topics and concepts that can help in learning through projects and engineering designs
- solving problems related to power and ways of getting it.
- using materials and tools from the surrounding environment to carry out integrative activities of science, technology, engineering and math.
- solving problems that face the process of saving power and using it to increase the high order thinking skills and creative thinking ones.
- Using recent technology tools to recognize the proteins and measure calories and fats that the body needs by inquiry, research, and discovery means.

3- Preparing the experimental unit (student's book)

The student's book was prepared while developing the chemistry book of third year secondary stage (chemistry 4) second semester (the electro-chemical and the bioorganic compounds units). The following table shows the lessons of the two units and the number of classes needed to cover them according to STEM Approach.

Table (3) plan of distributing the two units of electro-chemical and the bio-organic compounds

No	Unit	Topic	Periods
1	Fifth electro chemistry	Galvanic cells	16
2		Batteries	
3	Electricity The project of the unit	Electro analysis -------------------------- Getting power from solar panels	
		Renewed power: wind turbines	
4	Sixth Bio-organic compounds	proteins	9
5		carbohydrates	
6		lipids	
7		Nucleic acids	
8	Unit project	Cheating in milk Fat percent in your food	
9		total	25

The process of preparing the experimented units went through the following steps:

- Identifying the general objectives of the unit in light of the general objectives of chemistry curriculum of the secondary stage and those of third year secondary in light of STEM Approach, besides the higher order thinking skills (analysis, synthesis, evaluation), and creative thinking skills.
- Stating the content of the experimental unit (student book) : the content of the two units was developed and restated in light of STEM Approach

- Going back to resources related to chemistry teaching and to websites where there are models of lessons designed according to STEM Approach and scientific magazines specialized in teaching STEM
- The logical presentation of the unit; i.e. shifting from general to specific to perceive the relations between concepts and skills related to the two units. – solving problems of the Saudi community by developing the creative thinking skills and the higher order thinking skills.
- integrating activities that link concepts, the scientific, technological, engineering, and mathematical skills, and inquiry scientific activities and group handouts.
- engineering designs through project based learning and research and collecting data and the necessary tools to build the PROTOTYPE and developing and improving it so as to reach the final design.
- There should be projects at the end of the unit that students search for and carry out to solve specific problems along with writing and designing a poster that includes the steps of the project and its prototype.

Controlling the experimental unit and ensuring its suitability

After preparing the student's book in its initial form the researcher submitted it to a group of jury members to get their opinions:

- To what extent the experimental unit is related to the list of criteria in light of STEM Approach?
- To what extent the experimental unit is related to the prescribed general objectives.

- Correctness and accuracy of the scientific material involved.

4- Preparing the student's portfolio

The student's portfolio was prepared to involve the activities , group work handouts, tools of evaluating each lesson, and activities handouts , measures of grading and tools of evaluating projects that contribute to developing higher order thinking skills and students' creative thinking skills. There are enough spaces in the work handouts for students to record their responses and observations and the important deductions of the integrated activities. Tools of evaluation aimed at assessing the cognitive knowledge and the skills (such as the formative assessment, the summative assessment, the final assessment, peers assessment, observation cards, test of higher thinking (analysis, synthesis, evaluation, test of creative thinking and assessment of the projects and the engineering designs through a rubric . In this way the student can assess himself to know his points of weakness and points of strength. This will contribute in improving his learning skills and be better.

After arriving to the initial form of the portfolio, it was submitted to a group of jury members specialized in curriculum and methods of teaching to know their opinions in:

- To what extent the activities are related to the prescribed objectives.
- To what extent some pictures are clear and suitable for the prescribed activity
- To what extent the activities are suitable to the nature of STEM Approach

5-Preparing the teacher's guide: appendix (8)

When preparing the guide, it was taken into consideration that it should include

-Introduction: The guide starts by an introduction directed to the teacher of chemistry in which the philosophy behind the guide was clarified, besides the general objective that the guide seeks to achieve (teaching the two units in light of STEM Approach). It also clarifies the methods and strategies of teaching, the steps of the prototype, and of learning by projects.

Stating the lessons of the guide

The researcher distributed the content of the unit on 25 periods in the second semester 2021. The following is a description of the steps of presenting the lessons in the guide:

- Identifying the general objectives of the lessons in light of STEM Approach.
- Integrating STEM as for the scientific concepts, technology , engineering, and mathematics in each lesson
- Preparing the learning activities including the integrated inquiry, practical, and engineering designs and group handouts.
- The great challenges to the problems that face the community and trying to solve them and collecting data about them.
- Methods and strategies of teaching: learning through projects, learning through problems, and cooperative learning. materials, methods, models used in carrying out the activities and designs.

- Differentiating means of evaluation of the lessons, concepts, skills, projects and prototypes.

After finishing the teacher's guide, it was submitted to the jury members to be sure of :

- presentation of the scientific material of the unit developed according to STEM Approach.
- suitability of the guide to the unit objectives
- The relation of the teaching aids and the activities to
- the objectives of each unit should be clear.
- The relation of the projects to the prototypes and their suitability to the unit content.
- Contribution of the guide to the development of the higher order thinking skills.

Breparing the instruments of the study:

First: a test in higher order thinking skills (analysis, synthesis, evaluation) Appendix (9)

Objective of the test:

The test aims at assessing the ability of third year secondary stage students to develop the higher order thinking skills (analysis, synthesis, evaluation) in chemistry in the two units of electro-chemistry and bio-organic compounds in light of STEM Approach. The test has 40 MCQ questions divided into three sections that can help students develop the thinking skills.

Test Content

The test was constructed in light of the general aim of the test and its sub objectives. It measures the higher order thinking skills in the two research units. The items of the test covered all the objectives that can help develop the thinking skills of third year secondary school students.

Test table of specifications

Table (4) shows the specifications of the higher thinking skills test of the two units; the electro-chemistry and the bio-organic compounds of third year students.

Table (4) the specifications of the higher thinking skills test of the two units; the electro-chemistry and the bio-organic compounds of third year students.

topic	Higher thinking Skills١					
content	analysis	syntheses	evaluation	No, of questions	No. of periods	%
Galvanic cells	3	3	5	11	8	32%
Batteries	3	2	2	7	6	24%
electro analysis	2	3	3	8	6	24%
proteins	1	1	1	3	١	4%
carbohydrates	1	1	1	3	1	4%
lipids	2	1	1	4	2	%8
Nucleic acids	2	1	1	4	1	4%
No. of questions	14	13	14	40	25	
%	35%	30%	35%			100%

Constructing the higher order thinking skills test:

This test was in three parts that clarify the skills used in developing the higher order thinking skills of third year students in the covalent bonds unit and the expected objectives were taken into consideration when stating them.

5-Defining the scoring system:

The scoring system was giving one score to each of the MCQ correct response. The total number of the test items were (40) .

Instructions of the test

The instructions of the test were written in the first page of the test. It includes recording the data of the student on the test paper, the number of items, how to respond, timing, and the necessity of responding to all items of the test

The test was administered to a pilot sample of 20 third year students from Forsan al Gezera school at KHarg demonstration in the second semester 2020/ 21 to define the following:

Calculating validity

Test validity was calculated through:

The arbitrators validity

The arbitrators validity was used to ensure test validity, This happened by submitting the test to a group of jury members specialized in curriculum and instruction to ensure if:

- test items are suitable to third year students.
- test items represent the higher order thinking skills
- each test items measures what it is supposed to measure.
- linguistic and scientific verification of the items.
- This will happen by adding or omitting or rephrasing any of the test items.

The arbitrators agreed on

- The suitability and accuracy of the test items.
- A number of items need to be rephrased and some others are not suitable. The items they referred to were omitted and were substituted according to their observations in coordination with the supervisory committee.

Formative validity:

The formative validity of high order thinking skills test was calculated through

Internal consistency:

Coefficient correlation between each item in the test and the higher skill it measures, and between it and the total score of the test. It was evident that all correlations are significant at 0.05 and 0.01 levels of significance. This ensures the formative validity of the higher thinking skills test.

Discrimination validity

To ensure the discriminating power of the higher thinking skills test , the power of discrimination was calculated. 27% of the high scores in the pilot sample and 27% of the low scores of the pilot sample. Mann-Whitney test was used to identify the significance of differences between means of scores. It was clear that there was a significant statistical difference at 0.05 level between highs and lows.

Reliability of the higher order thinking skills test

Reliability of this test was calculated using Cronbach Alfa. The reliability (0.958) is high. This shows that the test is reliable and its results are trusted.

Index of difficulty and facility:

Index of difficulty of each item of the higher order thinking skills test was found by calculating the means of scores of the correct responses (Salah el Din Allam).Index of difficulty ranged between (0.3o-0.65). The item is accepted if its difficulty ranges between (0.15 – 0.85) (Sobhy abo Galala 1999:221). The item less than 0.15 is very difficult and the item more than 0.85 is very easy. Index of discrimination of test items ranged between (0.33-0.83). Index of discrimination is accepted if it is more than (0.2). Therefore, the higher order thinking skills test has the power to discriminate between the students of the study.

Time duration

Means of scores were used by calculating the time taken by each student to respond to the test items divided by the number of the students in the pilot study. The average was taken to be (50) minutes.

Second: the creative thinking skills test:

Torrance creative thinking test was used.(Appendix 10). It is a wide spread test accepted by educationalists. It can be applied individually or in groups. It includes a verbal version that has six activities. These are (directing questions),(guessing reasons),(guessing results), (improving production) .(uncommon uses), (suppose that…). These six creative thinking skills measure (fluency, flexibility, and originality)

a-Stating the objectives of the test:

This test aimed at assessing students' ability to practice the creative thinking skills of (fluency, flexibility, and originality)

b- Stating the test specifications:

test questions cover the three creative sides of, fluency, flexibility, and originality) . Besides covering the following components of each skill:

Fluency skill

This skill includes activities related to the skill in which the student is required to write as many words as possible.

Flexibility skill

Activities related to this skill require writing as many uses as possible of unfamiliar alternatives, or improvements, or changes.

Originality skill:

This skill includes activities that require the student to write as many unfamiliar guesses as possible and mention what happens to a certain system if it changed to something else not found.

C- Stating instructions of the creative thinking skills

Instructions of the test are considered very important in constructing measures and tests. The following points are considered when stating the instructions of the creative thinking test:

- stating the instructions in correct language and suitable to the level of third year secondary school students
- identifying the time of the test as a whole and of each sub component
- instructing students to respond to each item in the test according to the allotted time.

D-piloting the creative thinking test:

The test was piloted on a group of third year secondary school students (20) in the second semester 2020/ 2021 to do the following

Test validity

This was measured through the following ways

Formative validity

Formative validity to measure test items through using the correlation coefficient between each item and the total skills of the test. It was clear that all correlation coefficients are significant at (0.05 and 0.01 levels. This ensures the formative validity of the creative thinking test.

Discrimination validity

To ensure the discriminating power of the creative thinking skills test, the power of discrimination was calculated. 27% of the high scores in the pilot sample and 27% of the low scores of the pilot sample. Mann-Whitney test was used to know the significance of differences between means of scores. It was clear that there was a significant statistical difference at 0.05 levels between highs and lows and it has a high level of discrimination.

Reliability of the creative thinking skills test

Reliability of this test was calculated using Cronbach Alfa. The reliability (0.883) is high. This shows that the test is reliable and its results are trusted

Time duration

Means of scores were used by calculating the time taken by each student to respond to the test items divided by the number of the students in the pilot study. The average was taken to be (60) minutes.

Conducting the experiment

Choosing the sample of the study and dividing them into two intact groups:

The research was applied on two intact groups from third year secondary school at the learning administration at Kharg governorate , Forsan al gezera school according to the unit taken from the suggested perspective of developing the chemistry curriculum at Saudi Arab kingdom in light of STEM Approach . Another group 36 students formed the control group and were taught by the regular method of teaching.

The experimental design.

This is an experimental research in which the effect of an independent variable or more on a dependent variable was studied. Therefore, one of the experimental designs (Pre-post) control group designs was used.

Procedure of the experimental design

1-The two intact groups:

To know the effect of the independent variable (the suggested unit from the suggested perspective of developing chemistry curriculum in light of STEM Approach) on the other two dependent variables, the high order thinking skills and the creative thinking skills, it was necessary to control the intervening variables that might have effect on dependent variables. The differences between the two groups on the two tools of the study were calculated and no statistical significant differences were found between groups.

Conducting the research

The researcher applied the pretests, then taught the experimental group (36) students. According to the units taken from the suggested perspective of chemistry curriculum which was developed in light of STEM Approach for third year secondary school. While the control group (36) students were taught using the regular method of teaching. The research continued 5 weeks in the second school semester from 2020/ 2021 from 1/2/2021 to 10/3/2021 (5) periods a week.

Results and interpretations

Results related to the first question ' what are the criteria that should be there in the chemistry curriculum in light of STEM Approach?

The first question was answered when the criteria were defined in the procedures of the study.

Results related to the second question ' To what extend are the criteria represented in the present chemistry curriculum?

The researcher analyzed the content of chemistry curriculum of third year secondary school students in light of STEM Approach.

Through this analysis the researcher could arrive to

Weakness of "engineering design criterion" as its indicators are not included in the chemistry curriculum of third year. as the percentage of availability is 5.30 % and unavailability is 94.71% .

Many indicators of integration of STEM are not found in the chemistry

Curriculum of third year as the percentage of availability is 15.25 % and that of unavailability is 84.75.

The criterion of material, tools and technology means is very weak as many of its indicators are not represented in the chemistry Curriculum of third year. As it reached 6.44% and 93.56% for not available. This came as the second highest unavailable criteria in the curriculum.

The indicators of the criterion of activities, and learning tools that were found in the chemistry curriculum are low as its availability is 16.33% and unavailability is 83.67%.

The chemistry curriculum does not have any self-evaluation means or peer evaluation or project learning evaluation and its indicators were very weak as their availability is 14.67% and unavailability is 85.33%.

Curriculum objectives criterion was very weak as the percentage of availability is 20.64% and unavailability is 76.36%

Results related to the study hypotheses, analysis and discussion:

Discussion of the results related to the first hypothesis:

To ensure the validity of the first hypothesis of the study which states that there were statistical significant difference at 0.05 level between means of scores of the two groups, the experimental and the control in the post application of the higher order thinking skills test as a whole and in each skill in favor of the experimental group. 't' value was calculated. The size effect of the experimental treatment was calculated.. See the following table:

Table (5): 't; value of differences between means of scores of the experimental and the control groups in the post higher thinking skills test as a whole and in each of its sub-skills, and the size effect

level	group	no	mean	SD	"t" value	Sig.	df	size effect ($^2\eta$)
analysis	exp	36	12.25	2.63	6.629	0.01	70	0.386
	Cont.	36	7.14	3.80				
synthesis	exp	36	10.08	3.04	6.737	0.01	70	0.393
	Cont.	36	5.36	2.90				
evaluation	exp	36	12,03	2.74	5.887	0.01	70	0.331
	Cont.	36	7.69	3.46				
total	exp	36	34.36	8.18	6.748	0.01	70	0.394
	Cont.	36	20.19	9.58				

Table (5) shows that:

There were statistical significant differences between means of scores of the experimental and the control groups on the post higher thinking skills test as a whole and in each of its sub-skills, in favor of the experimental group on the post application. This indicates that the first hypothesis was accepted.

The size effect of the treatment on the post higher thinking skills test as a whole and on each of its sub-skills was between (0.331-0.394). It is a big and suitable value. This indicates that a big percentage of the differences were due to the experimental treatment. This shows also the effectiveness of the experimental treatment in the higher order thinking skills as a whole and in each one of the sub skills.

Discussion of the results related to the second hypothesis:

To ensure the validity of the second hypothesis of the study which states that there were statistical significant difference at 0.05 level between means of scores of the two groups; the experimental and the control on the post application of the thinking skills test as a whole and in each skill in favor of the experimental group, 't' value was calculated. The size effect of the experimental treatment was calculated.. See the following table:

Table (6): 't; value of differences between means of scores of the experimental group on the post higher thinking skills test as a whole and on each of its sub-skills, and the size effect

level	group	no	mean	SD	"t" value	Sig.	df	Size effect ($^2\eta$)
analysis	pre	36	3.78	1.29	19.788	0.01	35	0.918
	post	36	12.25	2.63				
synthesis	pre	36	2.97	0.88	13.387	0.01	35	0.837
	post	36	10.08	3.04				
evaluation	pre	36	4.25	1.50	14.349	0.01	35	0.855
	post	36	12.03	2.74				
total	pre	36	11.00	2.24	16.711	0.01	35	0.889
	post	36	34.36	8.18				

Table (6) shows that:

There were statistical significant differences at 0.05 level between means of scores of the experimental group on the pre- post higher thinking skills test as a whole and in each of its sub-skills, in favor of the post application. This indicates that the second hypothesis was accepted.

The size effect of the treatment on the post higher thinking skills test as a whole and on each of its sub-skills was between (0.837-0.918). It is a big and suitable value.

This indicates that a big percentage of the differences were due to the experimental treatment. This shows the effectiveness of the experimental treatment in the higher order thinking skills as a whole and in each one of the sub skills.

These results agree with those obtained by Ghanem (2015), Chien Lajium (2016), Ahmed (2916), Alkathamy (2016), Yildirm &Sevi (2017), AlDaood(2017), Al Zebedi (2017,), Esmael (2017), Sumarni and Kadarwani(2020), Wahono,et al (2020), Ugur et al (2020), Hu. Et al (2020), SHaera (2020).

These results can be interpreted as follows:

Being involved in the integrative activities of science, technology, engineering and math, students could discover the exchanging relations between concepts and their technological applications. This improved the skills of analysis, synthesis, and evaluation through participating in constructing and evaluating the activity.

The unit developed in light of STEM Approach contributed in finding a learning and encouraging environment to develop the higher thinking skills. Designing the projects contributed to developing students' skills and experiences and challenging the prototype as for defining the problem and posing a plan to solve it, building the initial model and trying to develop it to reach to the prototype and evaluate it using a rubric,

Self-evaluation and a checklist to evaluate the activity and the skill.

Learning based on projects (STEM PBL) through solar cells and designing smart house design which works by the solar power, and recycling an automobile model that works by the solar cells, and constructing wind turbines and fuel car and designing a Robot and programing it to do some tasks and solve problems that might face it to obtain the clean and renewed power, how to use it in our daily life. All this happens when developing the higher thinking and the creative ones.

Strategies of teaching also contributed in the developed unit which depends on learning by discovery, in enriching the learner's experiences through inquiry based learning, and in learning based on projects and problem solving, and learning through cooperative group work, and increasing students' motivation.

Enthusiasm and eagerness to solve problems and challenges. This appeared in the suggested solutions presented by students when working cooperatively in groups in building models by creative ways from the surrounding environment, like constructing DNA model, and building a car working by wind power and preparing soap using simple materials from home and carrying out some experiments like protein separation.

Students related society to their environment through the scientific and integrative projects and through some engineering challenges and simple experiments. This led to developing skills and experiences and positive participation of students in learning and improving their higher thinking skills.

Relating technology and electronic learning aids, and the virtual programs and simulation in an interactive environment through Clasira and TEMS FORUM and using the educational Robot EV3 to integrate STEM in building and designing the Robot , and programing the

Robot to carry out some tasks. All this was due to the developed unit in light of STEM Approach in which activities ensured the integration of the four fields.

Discussion of the results related to the third hypothesis:

To ensure the validity of the third hypothesis of the study which states that there were statistical significant difference at 0.05 level between means of scores of the two groups , the experimental and the control in the post application of the creative thinking skills test as a whole and in each skill in favor of the experimental group. 't' value was calculated. The size effect of the experimental treatment was calculated.. See the following table:

Table (7): 't; value of differences between means of scores of the experimental and the control groups in the post creative thinking skills test as a whole and in each of its sub-skills, and the size effect

level	group	no	mean	SD	"t" value	Sig.	df	Size effect ($^2\eta$)
fluency	exp	36	8.11	3.55	6.858	0.01	70	0.402
	Cont.	36	3.33	2.20				
flexibility	exp	36	8.86	3.30	6.578	0.01	70	0.282
	Cont.	36	3.89	3.11				
originality	exp	36	7.89	3.03	7.823	0.01	70	0.466
	Cont.	36	2,78	2.49				
total	exp	36	24.94	9.35	7.514	0.01	70	0.446
	Cont.	36	10.00	7.42				

Table (7) shows that:

There were statistical significant differences between means of scores of the experimental and the control groups on the post creative thinking skills test as a whole and in each of its sub-skills, in favor of the experimental group on the post application. This indicates that the third hypothesis was accepted.

The size effect of the treatment on the post creative thinking skills test as a whole and on each of its sub-skills was between (0.382-0.466). It is a big and suitable value. This indicates that a big percentage of the differences were due to the experimental treatment. This shows the effectiveness of the experimental treatment in the creative thinking skills test as a whole and in each one of the sub skills.

Discussion of the results related to the fourth hypothesis:

To test the validity of the fourth hypothesis of the study which states that there were statistical significant difference at 0.05 level between means of scores of the experimental group in the post application of the creative thinking skills test as a whole and in each skill in favor of the post application. 't' value was calculated. The size effect of the experimental treatment of creative thinking skills was calculated.. See the following table:

Table (8): 't; value of differences between means of scores of the experimental group in the pre-post creative thinking skills test as a whole and in each of its sub-skills, and the size effect

level	group	no	mean	SD	"t" value	Sig.	df	Size effect ($^2\eta$)
fluency	pre	36	4.28	2.51	7.896	0.01	35	0.640
	post.	36	8.11	3.55				
flexibility	pre	36	2.47	1,76	12.911	0.01	35	0.826
	post	36	8.86	3.30				
originality	pre	36	1.36	1.36	13.98	0.01	35	0.831
	post	36	7.89	3,03				
total	pre	36	8.11	4.98	13,048	0.01	35	0.829
	post	36	24.94	9.35				

Table (8) shows that:

There were statistical significant differences between means of scores of the experimental group on the post creative thinking skills test as a whole and in each of its sub-skills, in favor of the post application. This indicates that the fourth hypothesis was accepted.

The size effect of the treatment on the post creative thinking skills test as a whole and on each of its sub-skills was between (0.640-0.831). It is a big and suitable value. This indicates that a big percentage of the differences were due to the experimental treatment. This shows the effectiveness of the experimental treatment in the creative thinking skills as a whole and in each one of the sub skills.

These results agree with those of Aydinr (2017) , Shahali et al. (2017), Lay& Osman (2018), Rahmawati et al (2019) Ahmed (2916), Alkathamy (2016), Sumarni and Kadarwani(2020),Adhiriyanthi & Arifin(2021), Al Mohamadi (2017), Al Dorry (2018),and SHaera (2020).

These results can be interpreted as follows:

The present results are due to the following reasons:

Developing the two units in light of STEM Approach contributed effectively in finding a learning and encouraging environment through differentiated integrative activities that gather concepts and prototype with their technological applications and inquiry activities, besides using learning strategies based on projects , problem solving, discussions ,and debates among groups, inquiries, and brainstorming.

Learning based on prototype helped to provoke students' thinking with the aim of reaching to solutions to problems that might face them during constructing the prototype. Designing and constructing the models helped in developing the creative thinking (fluency, flexibility, and originality)

Using raw material from the surrounding environment to construct and design models and projects to develop creative thinking skills.

Developed the unit helped in involving students in projects, activities, and in scientific observations, predictions, and making perspectives for solving problems. This helped them to think like scientists so as to reach to the final model, and improving the creative skills of fluency, flexibility, and originality.

The developed unit with its integrating activities , scientific experiments, and engineering challenges that pose thinking provoking questions, and relating them to the students' lives and the problems they face like the power problem, and the use of the renewed power. All this helped in provoking the students' thinking to reach to solutions and contributed in improving the creative thinking skills.

Evaluation of projects and activities such as the observation sheet and peer evaluation and the rubric and group self-evaluation, project evaluation form and the instruction poster (panner) of the projects that contain material, tools, and results and give a clear idea of each project. All these contributed in developing the creative thinking skills of fluency, flexibility, and originality.

The findings of this research conform with those of Aydin-Gunbatar (2018), Adhiriyanthi & Arifin (2021) in the effectiveness of the developed unit that contains integrative activities and prototypes and inquiries to develop the creative thinking skills.

. Discussion of the results related to the fifth hypothesis:

To ensure the validity of the fifth hypothesis of the study which states that there were positive statistical significant correlation at 0.05 level between means of scores of the experimental group in the post application of the thinking skills test and their scores on the post application of the creative thinking test. Pearson Correlation coefficient was used to calculate the correlation between means of students' scores on the post creative thinking test. See the following table:

Table (9) Pearson Correlation coefficient between means of the experimental group students' scores on the post test of higher thinking skills test and creative thinking test .

Significance	Correlation	Variable
0.05	٠. 895	High thinking skills ◂◂ Creative thinking ◂◂

It is clear from table (9) that there is a strong positive statistically significant correlation at 0.05 level between the scores of the experimental group on the post application of the higher thinking skills test and their scores on the post application of the creative thinking test. This means that when their scores increased in high thinking test, they have also achieved increase in the scores of the creative thinking test.

These results are in accordance with those of Shehima (2015), Rehmat (2015), Hashash, (2018), aLdorry,(2018), Esiry, (2018, aLgalal(2018), Al ghamedi & Hussein (2019), and Sumarni& Kadarwati, (2020).

The researcher can interpret the correlation between the high order thinking skills and the creative thinking skills as follows:

- The two developed units depended on the engineering designs which basically depend on defining the problem and the great challenges and trying to reach to a suitable solution and to design a prototype model that helps to overcome challenges in a different and creative ways so as to help students use the high thinking skills and apply them creatively.
- Students cooperated to arrive to solutions and work in groups in a kind of learning based on projects and designing models, inquiries and brainstorming This led students to create and think in different ways to find solutions. This helped in developing the high order thinking skills and creative thinking.
- The integration between science, technology, engineering, and math
- (STEM)in concepts, activities, engineering designs, and using technology and math to understand science, helped in finding a correlation between the skills of analysis, synthesis, evaluation and creative thinking skills.
- The use of suitable evaluation tools to help in learning through projects, self-evaluation, the observation sheet, the rubric, the performance tests, the pre and post tests, all helped in this correlation between the high thinking and the creative thinking skills.

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