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The Effectiveness of STEM-Based Chemistry Teaching on Scientific Concept Acquisition Among Tenth-Grade Students

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Abstract: The study aimed to identify the effectiveness of STEM-based chemistry teaching in acquiring scientific concepts among the basic tenth grade students in the Directorate of education of the Koura Brigade, the study adopted a semi-experimental curriculum, and the study sample consisted of 50 students selected by random method distributed over two study divisions, where one of these divisions was randomly selected as an experimental group (the educational material was taught using the stem the number of its members was (25), and the study included a test of acquiring chemical concepts. The results showed that there is a statistically significant difference d at the level of significance ($0.05=\alpha$) between the two computational averages for the dimensional measurement of the acquisition of chemical concepts (in general) in the sample of tenth grade students, depending on the group variable (experimental, control), in favor of the experimental group that was taught using the stem input, and the study recommended training chemistry teachers to design and implement lessons according to the STEM input, and provide them with appropriate teaching strategies that support project-based learning and scientific investigation.

KEYWORDS

Effectiveness, STEM, acquisition of scientific concepts, tenth-grade students.

Highlight

- This quasi-experimental study of 50 tenth-grade students in Jordan's Koura Brigade Directorate of Education found that STEM-based chemistry teaching significantly improved scientific concept acquisition ($\alpha = 0.05$) compared with conventional instruction. The experimental group (25 students) outperformed the control group on the post-test, leading the authors to recommend training chemistry teachers to design STEM lessons that support project-based learning and scientific investigation.

Introduction

In response to the accelerated scientific transformations that characterize the current stage, interest in the Basic Sciences has become an increasing research interest, as a knowledge base on which sustainable development and technical renaissance are based. Investing in its education and curriculum development has become a fundamental reflection on the ability of contemporary countries to compete and innovate. Basic sciences are not limited to explaining natural phenomena, but extend to building systematic thinking practices, and establishing competence on analysis, reasoning and evidence-based decision-making, which leads to the preparation of individuals capable of conscious interaction with contemporary scientific and technological challenges.

In light of the importance of basic sciences and the interest in studying them and their prominent role in building contemporary societies, chemistry stands out as one of the most important Sciences in the scientific system, where chemistry is known as the science that investigates the study of materials in terms of their structure and the relationship of this structure with their properties and their interaction with each other to produce new materials (Zeitoun, 2007). Proceeding from this definition and its scientific function, chemistry plays a prominent role in technical and scientific progress, as it greatly helps in the development of Science and various industries and production intensity, and the study of chemistry enhances expertise in the field of chemical experiments in addition to contributing to enhancing the accuracy and control skills in the work of students (Ibrahim, 2009).

(Al-Shaya et al. 2022) have pointed out that despite this extreme importance of scientific concepts, the results of many educational studies have revealed that there are noticeable difficulties among students in teaching and acquiring scientific concepts, as studies have indicated that one of the most important factors in the failure of the science curriculum to not focus on learning concepts, in addition to using traditional methods of Education hinders the adjustment of perception and previous erroneous understanding of concepts.

This can be explained in the light of several factors, the most prominent of which is the acquisition by students of many scientific misconceptions in their reliance on learning those concepts and teaching them on rote memorization and memorization, which increases the percentage of forgetting them and not differentiating between them, and it also turns out that the acquisition of scientific concepts is not limited to memorizing or displaying them, but must be true and sound (Zeytun, 2015).

With the rapid changes in contemporary reality and the resulting social, scientific and technological changes, it is necessary to develop science education in line with these developments and enhance its ability to prepare students capable of organized thinking, deep understanding and linking knowledge to the realities of life, and the focus is no longer limited to the transfer of information, but the urgent need to adopt integrated, enabling him to face the challenges of the era consciously and efficiently (Khatibah and Fiqhi, 2022).

(Briney & Hill, 2013) defines STEM as learning and teaching science, technology, engineering and mathematics sufficiently to build thinking minds with the ability to solve problems, and (Merrill, 2009) defines it as education based on several criteria, where the role of science teachers is education based on an integrative input in education and achievement, and science is taught as an integrated unit.

(Khatibeh and Fiqhi, 2022) explain that the STEM fields consist of four main pillars that represent the foundations of this integrative trend; the letter (S) refers to science, and is intended to study the natural world and interest in understanding and clarifying its phenomena, and the letter (T) symbolizes technology, which is concerned with the use of scientific knowledge in modifying the natural environment to achieve human requirements and interests, and the letter (E) refers to engineering, namely an applied field in which natural and mathematical knowledge obtained through study and experience is employed in a systematic and conscious manner, with the aim of developing productive methods for investing natural resources in an economic manner that meets the interests of The letter (M) denotes mathematics, which is defined

as the science of abstract relationships, patterns and structures on which logical and quantitative thinking is based.

Within the framework of Educational Planning for the employment of the STEM portal, The National Foundation for Educational Research (NFER) outlined the most important goals of planning STEM activities, which revolve around building and promoting strategic partnerships, meeting local and national needs and situations and achieving compatibility with them, using strategies to effectively attract target groups, taking into account the critical determinants of success within the planning and implementation processes of the project, as well as including reflective practice in improving the quality of performance (al-Dosari, 2015).

Based on this, the STEM portal aims to implement the acquired skills and knowledge from the disciplines of Science, Technology, Engineering and mathematics in developing new solutions to real-life problems, building a generation qualified to contribute to advanced technical and scientific fields, as well as promoting the development of achievement in mathematics and science, establishing motivation and positive trends towards learning, developing critical and creative thinking skills, decision-making, and problem solving, in line with the requirements of technological development (Bunyamin & Finley, 2016).

The Study Problem and its questions:

Despite the growing international interest in the integration of curricula and educational outputs, the educational system still relies heavily in building curricula on the basis of separation between disciplines, which negatively affects the quality of the educational process and the efficiency of students; reflecting the existence of deficiencies in educational outputs, which does not adequately meet the requirements of the labor market, in particular in the fields of STEM science, technology, engineering and mathematics. Studies have shown the important role of the STEM portal as a Harbi study (2019) in the development of creative thinking and the development of the ability to solve problems using inquiry-based learning and collaborative work. The recommendations of a series of studies and conferences have also confirmed the need to develop educational curricula based on this curriculum to raise the level of scientific thinking skills, despite the obstacles that limit its effective application.

On the other hand, through the researcher's field experience as a chemistry teacher, he noticed that there are shortcomings and weaknesses among basic stage students in acquiring scientific concepts during chemistry teaching, and in response to the recommendations of many conferences and studies on the application of the STEM curve and linking it to the acquisition of scientific concepts, whose effectiveness has not been sufficiently addressed in the scientific literature, this study comes to investigate the effectiveness of teaching chemistry using the STEM entrance in the acquisition of scientific concepts among basic stage students towards learning chemistry.

The problem of the study is the following main question:

- What is the effectiveness of STEM-based chemistry teaching in acquiring scientific concepts among basic tenth-grade students?

Study hypotheses

- There are no significant differences at the level of significance ($\alpha \geq 0.05$) between the averages of the experimental group's scores

and the averages of the control group in the concept acquisition test attributable to the teaching method (stem input, the usual method).

The importance of the study

The importance of this study stems from the theoretical and applied importance of its subject aimed at investigating the effectiveness of the STEM entrance in teaching chemistry and its impact on the acquisition of scientific concepts, in light of the accelerated developments in contemporary education and the resulting trend towards the integration of knowledge and application.

The study aims to investigate the extent to which this approach contributes to improving the teaching of chemistry from a traditional to an integrative character that promotes the use of scientific knowledge in practical contexts, by promoting the construction of scientific concepts in a deeper and more permanent way.

Study limits

- Objective limits: the objective boundaries were limited to a unit of the chemistry textbook for the basic stage entitled chemical energy and the use of the stem input and its impact on the acquisition of scientific concepts.
- Temporal limits: this study was conducted in the academic year 2025/2024 second semester.
- Spatial limits: Jenin Al-Safa Comprehensive Secondary School for Boys, affiliated to the Directorate of Education of the Koura brigade.
- Human limits: this study was conducted on a sample of students of the basic stage / tenth grade at Jenin Al-Safa Comprehensive Secondary School for boys.

Study determinants

The results of this study are related to the characteristics and size of the selected sample, the measuring instruments used and the procedure for their application, and are also influenced by the nature of the statistical processing adopted in the data analysis.

Methods and procedure

This chapter includes a description of the study community, the study curriculum, its design, sample and study tools used in data collection, the procedures for its construction, its truthfulness and constancy, its variables and application procedures, and how to process its data to answer the study questions and reach the study results.

Study community

During the second semester of the academic year 2025/2024,

the study community consists of all students of the tenth basic grade in public schools affiliated to the Directorate of education of the Koura brigade, numbering (2612) male and female students, including (1315) male and(1297) female students, according to the statistics of the planning department in the Directorate.

Study personnel

During the second semester of the academic year 2025/2024, the study personnel were selected by the intentional method from the students of the tenth basic grade at Jenin Al-Safa Comprehensive Secondary School for boys belonging to the Directorate of education of the Koura Brigade, during the second semester of the academic year 2025/2024, numbering (50) students, divided into two study divisions, where one of these divisions was randomly selected as an experimental group (the educational material was taught using the stem entrance) and the number of its members reached (25) students, and the second division was considered as an officer group (it was taught by the number of its members (25) students.

Study tools

Test construction

- Determining the objective of the test: the objective of the test is to measure the level of acquisition of chemical concepts in the basic tenth-grade students contained in the module (compounds and chemical bonds) of the chemistry textbook for the basic tenth grade.
- Preparation of the specification table for the achievement test and relative weights, by analyzing the content of the study topics contained in the unit (compounds and chemical bonds) of the chemistry textbook for the tenth-grade basic to identify the concepts contained in the content.
- Formulation of Objective Multiple-choice questions the study material covers (24) paragraphs in front of each paragraph four alternatives to the answer, distributed over six areas, namely: determining the verbal significance, discovering the scientific concept, interpreting observations, using the concept in solving problems, using the scientific concept in reasoning, conclusion and generalization, and applying the concept.

The coefficients of difficulty and discrimination of the paragraphs of the test for the acquisition of chemical concepts

The difficulty and discrimination coefficients for the test paragraphs were calculated to determine the degree of difficulty of the test paragraphs and their distinctive strength, by applying the test to a survey sample consisting of (20) tenth-grade students at Jenin Al-Safa Comprehensive Secondary School for Boys affiliated with the director of education of the Koura brigade, as shown in Table (1).

Table (1): difficulty and discrimination coefficients for the paragraphs of the chemical concepts acquisition test.

Paragraph	Coefficient of difficulty	Coefficient of differentiation	Paragraph	Coefficient of difficulty	Coefficient of differentiation
1	0.65	0.48	13	0.60	0.58
2	0.80	0.51	14	0.75	0.51
3	0.70	0.48	15	0.55	0.77
4	0.40	0.74	16	0.45	0.59
5	0.55	0.45	17	0.35	0.44

Paragraph	Coefficient of difficulty	Coefficient of differentiation	Paragraph	Coefficient of difficulty	Coefficient of differentiation
6	0.65	0.49	18	0.75	0.54
7	0.75	0.66	19	0.35	0.47
8	0.65	0.47	20	0.40	0.50
9	0.80	0.42	21	0.45	0.75
10	0.75	0.50	22	0.50	0.58
11	0.40	0.45	23	0.55	0.48
12	0.75	0.60	24	0.65	0.44

It is clear from Table (1) that the values of the difficulty coefficients of the paragraphs ranged between (0.80-0.35), and the values of the discrimination coefficients ranged between (-0.42 0.77), and these values are acceptable to keep the paragraphs within the test according to the criterion of return (2010), which indicates the retention of the paragraph whose difficulty ranges between (0.80–0.20), and has a discrimination coefficient higher

than (0.39), therefore none of the paragraphs were deleted based on the difficulty coefficient or the final form of the test consists of (24) paragraphs, distributed over (6) areas.

Stability of the chemical concepts acquisition test

To estimate the constancy of the internal consistency of the test for the acquisition of chemical concepts and its fields; the Cooder-Richardson equation 20 (KR20-) was applied to the survey sample data, as shown in Table (2).

Table (2): values of the internal consistency coefficients of the chemical concept acquisition test with its macro significance and subfields

Testing and its areas	Constancy of internal consistency	Paragraphs
Determination of verbal semantics	0.80	4
Discovery of the scientific concept	0.82	5
Interpretation of notes	0.73	3
The use of the scientific concept in solving problems	0.83	5
The use of the scientific concept in inference, conclusion and generalization	0.81	4
Application of the concept	0.74	3
(Acquisition of chemical concepts (as a whole	0.85	24

It is clear from Table (2) that the constancy of the internal consistency of the scale as a whole amounted to (0.85), and the values of the coefficients of the constancy of the internal consistency of its subdomains ranged between (0.83 –0.73).

Verification of the equivalence of the two study groups in the acquisition of chemical concepts

To verify the equivalence of the two study groups in the pre

- test for the acquisition of chemical concepts with its overall significance, areas and sub-areas; arithmetic averages and standard deviations of the performance of the pre-study sample on the test were calculated, depending on the study group (control, experimental), Independent-Samples T-test was also used to detect the significance of the differences between the arithmetic averages, as shown in Table (3).

Table (3): (Independent - Samples T-test) results to reveal the significance of differences between the arithmetic averages of the performance of the members of the study sample on the test of acquisition of chemical concepts in its overall significance and its subfields, depending on the method of teaching.

Scope	Group	Arithmetic mean	Standard deviation	T Value	Degrees of freedom	Statistical significance
Determination of verbal semantics	Experimental Control	1.36 1.28	0.79 0.84	0.346	48	0.731
Discovery of the scientific concept	Experimental Control	2.20 2.35	1.21 1.14	0.451-	48	0.654
Interpretation of notes	Experimental Control	0.90 0.78	0.92 0.55	0.560	48	0.578
The use of the scientific concept in solving problems	Experimental Control	1.55 1.90	1.16 1.45	0.944-	48	0.350
The use of the scientific concept in inference, conclusion and generalization	Experimental Control	1.16 1.40	0.85 1.00	0.914-	48	0.365
Application of the concept	Experimental Control	0.69 0.60	0.89 0.61	0.416	48	0.679
Acquisition of chemical (concepts (as a whole	Experimental Control	7.86 8.31	3.04 3.36	0.496-	48	0.622

* A function statistically at the level of significance ($\alpha=0.05$)

It is clear from Table (3) that there are no statistically significant differences at the level of significance ($\alpha=0.05$) between the arithmetic averages of the performance of the members of the tribal study sample on the test of acquiring chemical concepts, with its total significance and its subfields attributable to the study group (control, experimental).

Study procedures

1. Reviewing the theoretical literature and previous studies related to the study tools, and building the study tools in their initial form.
2. Identification of the study personnel, who are the basic tenth grade students at Jenin Al-Safa secondary school for Boys, affiliated to the Directorate of education of the AL-Koura brigade.
3. Verifying the indications of honesty and stability of the study tools; by presenting them to a group of competent arbitrators, and applying them to a survey sample from the study community and from outside its sample from Jenin Al-Safa Comprehensive Secondary School for Boys affiliated with the Directorate of education of the Koura Brigade; in order to verify the psychometric characteristics of the tools.
4. Collecting the responses on the study tools, unloading them and entering them into the computer; to perform statistical manipulations using the SPSS program.

Study curriculum and design

To achieve the objectives of the study, the researcher used a semi-experimental design, with a pre-dimensional design of two groups with a variable teaching method (STEM input, and the usual method). The study design can be expressed symbolically as follows:



EG: Experimental group

CG: Control group

O1: The pre-and post-test for the acquisition of concepts.

X1: Processing (Steam Input)

Study variables

- I. The Independent Variable, which is: - The teaching method, and it has two categories: entrance (STEM), the usual method.
- II. The dependent variable, which is: - Acquisition of chemical concepts.

Statistical methods used

The statistical processing of the data in this study was carried out using the statistical package of Social Sciences (SPSS), as follows:
 - To answer the first question, the arithmetic averages and standard deviations of the scores of the study sample members were calculated in the pre-and post-metrology on the test of acquiring chemical concepts with its macro-significance and sub-fields, using the analysis of multiple mono-accompanying variance (MANCOVA), and the analysis of multiple mono-accompanying variance (MANCOVA).

Results

First: the results related to the second question, which stated: what is the effectiveness of STEM-based chemistry teaching in acquiring scientific concepts among basic tenth-grade students

To answer this question, the hypothesis of which stated: «there are no statistically significant differences at the level of significance ($\alpha=0.05$ between the average scores of the basic tenth graders in the control and experimental group in the acquisition of chemical concepts attributable to the teaching strategy input (STEM), the usual method)»; the values of arithmetic averages and standard deviations for the acquisition of chemical concepts (as a whole) as shown in Table (4).

Table (4): arithmetic averages and standard deviations for the acquisition of chemical concepts in their total significance among the members of the experimental and control groups in the pre-and post-measurement and adjusted according to the group variable

Group	.No	Pre-test Arithmetic mean	Post-test Standard deviation	Average Arithmetic mean	Standard deviation	Adjusted average	Standard error
Experimental	25	7.86	3.04	14.80	3.91	14.97	0.62
control	25	8.31	3.36	20.41	3.90	20.24	0.62

It is clear from Table (4) that there are apparent differences between the arithmetic averages for the acquisition of chemical concepts (as a whole) in the members of the experimental and control groups of tenth grade students in telemetry depending on the group variable in favor of the experimental group in which the stem input was used to teach, and to verify the essence of the

apparent differences, the accompanying mono-variance analysis (One way ANCOVA) was used, after taking into account the degrees of pre-measurement for the acquisition of scientific concepts (as a whole) for each of the groups, as an accompanying variable, as shown in Table (5).

Table (5): the results of the accompanying monovariance analysis (One way ANCOVA) for the dimensional measurement of the acquisition of chemical concepts (as a whole) in the individuals of the study sample depending on the group variable

Source of variability	Total squares	Freedom degrees	Squares average	F Value	Level of significance	Eta square ()
Pre-test	21.226	1	21.226	2.219	0.143	
Teaching method	345.399	1	345.399	*36.114	0.000	0.435**
Error	449.509	47	9.564			
Total	864.136	49				

* A function statistically at the level of significance ($\alpha=0.05$)

** (The size of the effect according to Kilani and sherifin, 2014: weak (less than 0.06), medium (0.06-0.15), large (0.16 and above)).

Table (5) shows that there is a statistically significant difference at the level of significance ($0.05=\alpha$) between the two computational averages of the dimensional measurement of the acquisition of chemical concepts (as a whole) in the sample of tenth graders depending on the group variable (experimental, control), in favor of the experimental group that was taught using the input (STEM).

The size of the effect resulting from the use of the STEM input in the development of the acquisition of chemical concepts (as a whole), which is indicated by the value of the ETA square ($N^{43.50\%}$) (2), and this value is high according to Al-Kilani and Al-sharifin (2014).

The arithmetic averages and standard deviations of the pre -, post-and adjusted measurement of the areas of acquisition of chemical concepts were also calculated depending on the group variable (experimental, control), as shown in Table (6).

Table (6): arithmetic averages and standard deviations of the fields of acquisition of chemical concepts among the members of the experimental and control groups in the tribal and dimensional measurement and adjusted according to the group variable.

Scope	Group	.No	Pre-test		Post-test		Average	
			Arithmetic mean	Standard error	Arithmetic mean	Standard error	Arithmetic mean	Standard error
Determination of verbal semantics	Experimental	25	1.36	0.79	2.73	1.16	2.75	0.16
	Control	25	1.28	0.84	3.84	0.37	3.82	0.16
Discovery of the scientific concept	Experimental	25	2.20	1.21	3.51	1.40	3.55	0.21
	Control	25	2.35	1.14	4.50	0.88	4.46	0.21
Interpretation of notes	Experimental	25	0.90	0.92	1.84	0.92	1.84	0.15
	Control	25	0.78	0.55	2.31	0.84	2.31	0.15
The use of the scientific concept in solving problems	Experimental	25	1.55	1.16	3.11	1.16	3.26	0.27
	Control	25	1.90	1.45	3.90	1.75	3.75	0.27
The use of the scientific concept in inference, conclusion and generalization	Experimental	25	1.16	0.85	2.01	1.23	2.05	0.17
	Control	25	1.40	1.00	3.16	0.85	3.12	0.17
Application of the concept	Experimental	25	0.69	0.89	1.60	0.79	1.58	0.11
	Control	25	0.60	0.61	2.70	0.43	2.72	0.11

It is clear from Table (6) that there are apparent differences between the arithmetic averages of the fields of acquisition of chemical concepts among the members of the experimental and control groups in telemetry depending on the group variable in favor of the experimental group in which the stem input (STEM) was used to teach, and to verify the essence of the apparent differences, multiple accompanying single variance analysis (one way MANCOVA) was used, to find out the impact of the stem input on each field of acquisition of chemical concepts, after taking into account the degrees of tribal measurement on each field separately for both groups.

Results discussion

Discussion of the results of the main study question, which stated: «what is the effectiveness of STEM-based chemistry teaching in acquiring scientific concepts among basic tenth grade students?»

The results showed that there is a statistically significant difference at the level of significance ($0.05=\alpha$) between the two computational averages for the dimensional measurement of the acquisition of chemical concepts (as a whole) in the sample of tenth grade students depending on the group variable (experimental, control), in favor of the experimental group that was taught using the stem entrance, and in the researcher's opinion, this result is due to the educational advantages of this entrance based on integration between its various fields; which leads to the presentation of scientific

knowledge in a coherent manner that helps The integration of these areas allows students to employ scientific concepts in life situations and practical applications, which enhances the integration of their knowledge and makes the learning process more relevant to daily life.

The superiority of the students of the experimental group can also be explained by the fact that the STEM entrance is based on active teaching strategies that focus on the learner's role in building knowledge through investigation and collaborative work, as they are educational practices that contribute to improving the understanding of scientific concepts rather than limited to memorization .students' participation in applied activities and educational projects based on solving scientific problems is able to provide an opportunity to explore chemical concepts and apply them in multiple contexts. this contributes to the consolidation of these concepts in their knowledge structure and enhances their ability to use them in new situations.(Bybee, 2013)the results of the current study are in agreement with the results of the study of both: (Abu Farha, 2015; a street Study, 2017; Fakhro, 2020; Siyam, 2021; Sabri and Nassar, 2021; Majali, 2022).

The results showed that the computational averages of the effectiveness of STEM-based chemistry teaching in the acquisition of scientific concepts among the basic tenth grade students in the field of (applying the concept), has come in first place, and this can be explained educationally that the STEM entrance is based mainly on linking theoretical knowledge and practical applications through

integrative activities that include science, technology, engineering and mathematics, which allows students transformation of the abstract concept To an applied practice that can be observed or applied.

On the other hand, the results showed that the computational averages of the effectiveness of STEM-based chemistry teaching in acquiring chemical concepts among tenth grade students in light of their learning patterns in the field of (using the scientific concept in problem solving) came in last place, and the result can be interpreted based on the nature of scientific problem solving skills, these skills need higher levels of thinking such as analysis, synthesis, scientific reasoning, and the ability to link two or more scientific concepts simultaneously, and these skills also need a longer period of training and consistent practice among them; so that students can practice them and then mastering it (Sanders, 2009).

Recommendations

* Using the STEM entrance in teaching chemistry at the secondary level more broadly, because of its positive impact on the development of the acquisition of chemical concepts among students.

* Train chemistry teachers to design and implement lessons according to the STEM portal, and provide them with appropriate teaching strategies that support project-based learning and scientific inquiry.

* Reorganizing some topics of chemistry curricula to allow the application of the STEM entrance in an integrative manner, focusing on linking chemical concepts with real-life applications.

* Conducting future studies that address the impact of the STEM input on other educational variables such as scientific thinking, creative thinking, and the trend towards chemistry at various academic stages.

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