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Effectiveness of Exploratory activities Based on Engineering and Science Practices of Next Generation Science Standards in Developing Exploratory Thinking among Elementary Students

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A R T I C L E I N F O

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A B S T R A C T

The present research paper aimed to identify the effectiveness of exploratory activities based on engineering and science practices of Next Generation Science Standards (NGSS) in developing exploratory thinking among elementary students in Mecca, Saudi Arabia. The author utilized the quasi-experimental method based on the control and experimental groups. Moreover, the sample consisted of (64) 4th grade elementary female students. The "Unit of Energy" was restructured based on engineering and science practices of NGSS among the 4th grade elementary students. A teacher guide and a student notebook concerning the activities of the "Unit of Energy" were prepared. Moreover, an exploratory thinking test was developed and applied to the participants over 6 weeks. The results showed statically significant differences at the level of ≤0.01 between the mean scores of the experimental and control groups at exploratory thinking post-test and in each domain. The study recommends the need for teacher preparation programs at Colleges of Education on preparing the pre-service teachers according to NGSS that should be involved in teaching practices to evaluate pre-service teachers' performance in practicum.

1. Introduction

Science is an analytical subject that relies on the interactionbetween man and the environment through studying nature. Course designers should utilize knowledge and modern learning technology such as, Virtual Reality (VR) and Augmented Reality (AR) to serve society and solve problems (Omar, 2017; Sharma, 2022). According to LaDue and Manning (2015), NGSS motivate students to the processes and skills of scientific exploration and data analysis, especially in the elementary stage in which they are trained in thinking and behaving like scientists and engineers (Isabelle, 2017). In other words, science learning based on NGSS emphasizes exploring life phenomena by integrating engineering and science practices (SEPs) with scientific content. Instead of mastering learning steps theoretically, students are motivated to practice exploratory activities on real phenomena, including asking questions, solving complex problems, developing hypotheses, designing and conducting experiments, testing and discussing data, constructing arguments, and discussing results (Kuhn et al., 2017; Wardani et al., 2022).

Krajcik and Merritt (2012) and Krajcik et al. (2014) argue that asking questions direct students towards unreachable horizons, allowing them to think and involve with the content, provide solutions, and explain phenomena logically. Accordingly, it is important for students to develop exploratory thinking. The practices of exploration and research skills, generating models, analyzing data, and using statistics and probabilities are effective and common tools in science. However, they are neglected. Several authors recommend including these practices effectively in the content to achieve better results in science teaching and learning (Sneider et al., 2014; Grapin et al., 2022). NGSS-based exploration motivates students to challenge ideas, ask questions, provide and test explanations, and communicate them to others (AbdelKarim, 2016).

The objective of Saudi Vision 2030 concerning education is to provide opportunities, improve the quality of educational outcomes, increase the effectiveness of scientific research, encourage creativity and innovation, develop community partnership, upgrade the capabilities and skills of education personnel, filling the gap between higher education outputs and labor market requirements, develop general education, guide students towards appropriate career options, and provide opportunities to rehabilitate students and move flexibly between different educational paths (Alotiaby & Aljaber, 2017; Albiladi, 2022). It could not be achieved but by providing a learning environment that triggers student thinking and inquiry. Many studies, such as Alahmad and Almoqpl (2016), Alrobayan and Alhammamh (2017), Haag and Megowan (2015), Kuhn et al. (2017), and Rawashdeh (2018) demonstrated the need to employ and integrate SEPs into science learning.

2. Statement of the Problem

Because of education development in Saudi Arabia, the new and translated science courses rely on (McGraw-Hill) to develop the capabilities, innovations, and skills of students. The literature demonstrated the poor level of Saudi students. For example,

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Guessoum (2013) reported a low level of students on the 2007 and 2011 tests. These findings matched the ones reported by Alshamrani, et al. (2016) concerning the low level of students in performing the TIMSS test in 2015. Moreover, Alotiaby and Aljaber (2017) indicated the lack of NGSS indicators in the "Unit of Energy" for the 6th elementary and the 1st and 2nd middle students. Alahmad and Albogami (2017) illustrated the low level of the main ideas, SEPs, and comprehensive concepts in the energy domain at the secondary stage physics textbooks. Additionally, Alrobayan and Alhammamh (2017) emphasized the reduced availability of SEPs of NGSS in science textbooks among 1st grade middle students. Issa and Ragheb (2017) indicated the low level of achieving NGSS and the 3rd elementary grade, such as using mathematical and computational thinking, building interpretations, designing solutions, and engaging in scientific controversy.

2.1 Questions

The present research paper seeks to answer the following main question:

"What is the effectiveness of using exploratory activities based on SEPs of NGSS in developing exploratory thinking among elementary students?

The main question is subdivided into the following minor ones:

1. What exploratory activities are based on SEPs of NGSS among 4th grade elementary students?
2. What is the effectiveness of using exploratory activities based on SEPs of NGSS in developing exploratory thinking among 4th grade elementary students in Mecca, Saudi Arabia?

2.2 Objectives

The research paper aims to:

1. Restructure the activities of the "Unit of Energy" for the 4th elementary grade in light of exploratory activities based on SEPs of NGSS.
2. Examine the effectiveness of using exploratory activities in the "Unit of Energy" based on SEPs of NGSS in developing exploratory thinking among 4thgrade elementary students in Mecca, Saudi Arabia.

2.3 Significance

1. The present research paper examines NGSS as the latest and most contemporary international standards in science teaching.
2. It may benefit curriculum developers to employ NGSS in developing the delivery of science activities in various disciplines (e.g., biology, physics, geoscience, engineering, and technology).
3. It tackles exploratory thinking that develops the capabilities of students to research by asking questions about the surrounding environment, thinking about the evidence-interpretation relationship, as well as developing activities to collect, organize, and analyze data.
4. It is applied to the elementary stage, in which students are provided with scientific and practical basics of SEPs.

2.4 Limitations

Subject limitations:

- Activities of the "Unit of Energy" of the science course for the 4th elementary grade.
- Exploratory thinking test that covers (observation, interpretation, experiment, definition, conclusion, using numbers, classification, hypotheses, and impact of variables).

Temporal limitations: The study was applied in the second semester of 2019/2020.

Human limitations: A sample of 4thgrade elementary students.

2.5 Definition of Terms

- NGSS are procedurally defined as a set of performance indicators to be achieved by 4thgrade students at the end of the exploratory activities of the "Unit of Energy".
- SEPs- based exploratory activities are scientific activities and experiments, covering the topics of the "Unit of Energy" of the science course for 4thgrade in the second semester of 2019/2020.
- Exploratory thinking comprises nine (9) domains that a student performs by employing SEPs of NGSS to reach scientific knowledge or study scientific phenomena included in various activities in the "Unit of Energy" of the 4thgrade science textbook.

3. Theoretical Framework and Literature Review

NGSS provide a new vision to engage students in SEPs. These practices are the first domain of NGSS. Thus, students integrate into the content and problem-solving by linking theory to practice. (Schaben et al., 2022).

3.1 Significance of SEPs

Scientific activity shows the science vision as a set of practices, illustrating that developing theories, illustrations, and finding solutions are a set of activities carried out by scientists and engineers. These practices cover a network of participants and specialized methods for research and writing, developing models to represent different systems and phenomena, making inferences, developing tools, and testing hypotheses through experiment or observation (The National Academies Press, 2012). The National Academies Press (2013) reports several logical justifications for employing SEPs in grades (K-12), such as

- Understanding the evolvement of scientific knowledge.
- Appreciating a wide range of methods that uses exploration, modeling, and interpreting global phenomena.
- Understanding the work of engineers, linking engineering and science, and having a deeper understanding of comprehensive concepts and basic ideas.
- Understanding interconnected concepts and basic ideas of science and engineering.
- Arousing students' curiosity and interest, motivating them to pursue studies, and forming positive attitudes.

According to Lee et al. (2013), the National Academies Press (2013) Wilson et al. (2015), and Andersen et al. (2022), the eight SEPs that the framework identified should be mastered by all students are:

SEP (1) Asking questions and defining problems: Students should be able to ask questions about the texts they read, the phenomena feature they observe, and the conclusions they draw from their models or scientific exploration. For engineering, they should ask questions to define the problem and its constraints.

SEP (2) Developing and using models: Modeling can begin in the earliest grades, from concrete pictures or physical models (e.g., a toy car) to more abstract representations of relevant relationships in later grades, such as a diagram to illustrate the relations between variables. In engineering, models may be used to analyze a system, test potential solutions, and evaluate a design and communicate its features to others.

SEP (3) Planning and carrying out investigations: Students should have the opportunity to plan and implement various forms of investigations in grades (K-12) that ranged from those structured by teachers to expose an issue or question that is impossible to explore on their own (e.g., measuring materials' features) to those emerged by their own questions.

SEP (4) Analyzing and interpreting data: Students are expected to expand their capabilities to use a range of tools for graphical representation, visualization, statistical analysis, interpreting data, and using mathematics to represent relationships between variables.

SEP (5) Using mathematical and computational thinking: They are two tools for understanding and representing physical variables and their relationships and predicting physical systems behavior in various forms, such as analyzing, expressing, and applying data statistically.

SEP (6) Constructing explanations and designing solutions: Scientific explanations are applications of a particular theory or phenomenon often depending on a model including a claim that how two or several variables relate to another variable or a set of variables in response to a question.

SEP (7) Engaging in argument from evidence: The study of science and engineering should focus on producing and defending a new idea or an explanation of a phenomenon.

SEP (8) Obtaining, evaluating, and communicating information: Science and engineering education develops students' ability to read and produce domain-specific text.

3.2 Guiding principles

The National Academies Press (2012) reports that the development of NGSS provides guidelines to use SEPs, as follows:

1. Students in grades (K-12) should be involved in all eight practices in each academic domain. NGSS identify the abilities that are expected to be acquired by students at the end of each academic domain (K-2, 3-5, 6-8, and 9- 12). Students' abilities to use these practices increase over time.
2. SEPs grow in complexity and sophistication from one grade to another. Thus, students' abilities should progress as they engage in science learning. For example, the practice of "planning and carrying out investigations" begins at (K-2) level with guided situations to identify phenomena and to observe, measure, and record outcomes. In the upper elementary grades (3-5), students should be able to plan and implement investigations that are expected to increase, including the complexity of questions and the nature of research.
3. Each practice may reflect the nature of science or engineering based on the objectives of the activity, including answering a question (science) and identifying and solving a problem (engineering).
4. SEPs represent what students are expected to do. The framework offers suggestions for instruction, such as explorations to solve a problem.
5. The eight SEPs are overlapped and interrelated. For example, the practice of "asking questions" may lead to the practice of "modeling" or "planning and carrying out investigations," which in turn may lead to "analyzing and interpreting data". The practice of "mathematical and computational thinking" may include some aspects of "analyzing and interpreting data".
6. Performance expectations focus on some practice-related abilities. Thus, the framework identifies the appropriate abilities associated with each class.

Several studies examined SEPs based on NGSS. For instance, Rowland (2014) showed the effectiveness of students' engagement in SEPs to develop their understanding of biological concepts, increasing their motivation to learn, and the absence of integration impact of NGSS on student awareness concerning teacher care. Fick (2014) reported students' ability to build and develop models. Abu Laila (2015) focused on developing a scientific activities program in the elementary stage based on quality standards and concluded the achievement of self-efficacy among students, including student responsibility for learning, social interaction, peer evaluation, and self-organization.

Kawasaki (2015) found varying degrees of alignment between teachers' performance and classroom learning owing to NGSS objectives. Because misunderstanding the objectives of NGSS makes it difficult to apply these practices, training programs are important for pre-service and in-service teachers. Qablan (2016) aimed to identify the potential of science teachers to change their abilities when designing and implementing science lessons. The results indicated how the participants greatly benefited from the training program in designing and implementing lessons based on research and exploration, which affected their students' engagement in SEPs. In contrast, their ability to ask questions and carry out investigations was not at the required level.

Almomani (2016) developed a unit based on NGSS and its impact on the practices, achievements, and attitudes of 8thgrade students towards sciences in Jordan. The results showed the degree of included NGSS in the developed unit was 84%. Most of the participants (73%) adopted NGSS vision. There are statistically significant differences in the achievement of experimental group students favoring the post-test. Elbaz (2017) indicated the effectiveness of developing the chemistry curriculum for the 1stgrade secondary students in light of the engineering design of NGSS to develop the achievement and SEPs. Abdelkarim (2016) demonstrated the effectiveness of a training program based on NGSS in developing a deep understanding, scientific exploration skills, and scientific controversy among elementary stage science teachers. Kuhn et al. (2017) highlighted the effectiveness of students' practice of science practices on increasing a deep understanding of science, developing research and analysis skills, and evaluating information.

Shoman (2018) addressed the development of the physics curriculum at the secondary stage based on NGSS to develop critical thinking and deep understanding. The results revealed that NGSS is not available in the physics curriculum, critical thinking, and deep understanding. Rawashdeh (2018) examined the effectiveness of a training program for science teachers in Jordan based on NGSS in developing SEPs and self- efficiency. Ezzeldin (2018) aimed to provide activities based on NGSS to develop SEPs, critical thinking, and scientific interests among elementary students in Saudi Arabia. The results found statistically significant differences between the mean scores of the pre and post-test of the experimental group in SEPs, critical thinking, and scientific interest favoring the post-test.

Kang et al. (2018) aimed to evaluate the results of educational content knowledge and support students in developing SEPs based on NGSS. The results revealed the awareness of teachers of educational content and their ability to support students. Malkawi and Rababah (2018) aimed to verify that the twelfth-grade teachers in Jordan utilizing SEPs based on NGSS. The results revealed that science teachers moderately incorporate SEPs in their teaching. In addition, no statically significant differences between the practices of science teachers in applying SEPs owing to the demographic variables (i.e., specialization, educational qualification, and teaching experience), while there were differences between the practice of science teachers based on gender favoring females.

Athera (2019) aimed to identify the level of practicing the NGSS among (64) physics science teachers. The results concluded the poor knowledge of teachers concerning the pivotal ideas of physics based on NGSS. Although they implemented most of SEPs, they do not have an adequate understanding and applying engineering practices. Wilcox (2020) addressed the impact of the professional development activity of teachers based on NGSS in 15 international schools delivering an American curriculum. The study found a statistically significant impact on teachers' understanding of NGSS in all spheres and improving teachers' practices in the classroom and their collaborative professional practices.

Although the previous studies varied in exploring NGSS, no study examined using exploratory activities based on SEPs in developing exploratory thinking skills for elementary students.

Thus, the present research benefited from them in identifying NGSS, how to use them in teaching, and determining the type of SEPs and the appropriate exploratory activities for the elementary stage. It also benefited from literature in developing research tools and materials.

3.3 Exploratory thinking

According to Shamsudin et al. (2013), exploration collects information through investigation, including asking questions about phenomena, examining a specific problem, as well as constructing knowledge that requires critical thinking, making observations, doing experiments, reaching conclusions, thinking creatively, and using intuition. Thus, it means understanding the characteristics of science with scientific experimentation. It includes structuring hypotheses, scientific conclusion, drafting scientific interpretations, and providing evidence (Saleh & Elsayed, 2014; Zaitoun,2010). As an educational method, exploration is based on facing the student with a problem, allowing self-confront, and problem-solving (Qurani,2013). Several studies aimed to develop exploratory thinking skills. For example, Rashed (2010) indicated the effectiveness of a developed unit based on self-learning practices in developing scientific research skills and curiosity among elementary students. Alafify et al. (2011) investigated the effect of the coupled-inquiry cycle in the development of exploration skills in science among the 8th-grade students. The results showed statically significant differences between the arithmetic means of experimental and control groups and the pre-test and post-test in exploration skills, including asking questions, designing experiments, analyzing, and interpreting, as well as the overall skills favoring the experimental group. Moreover, there were no differences in designing experiments and activities and analysis skills.

Hassan et al. (2011) indicated the effectiveness of teaching based on academic achievement, development of scientific research skills, and innovative thinking in physics for secondary students in Dakahlia, Egypt. Saleh and Elsayed (2014) investigated the effect of teaching by using the inquiry wheel model, problem-solving method, developing cognitive achievement traditionally, scientific exploration skills, and motivation for science learning among the 2ndgrade middle students. The results indicated the superiority of the two experimental groups students on the control group students. Nichols et al. (2017) analyzed the effect of teachers' usage of the exploration approach in science teaching compared to traditional teaching. The results showed that the use of this approach led to the development of questioning skills and the opportunity for teachers to enhance exploration skills for students. Kruit et al. (2018) examined the effect of explicit instructions on the acquisition of exploratory thinking skills, Explicit instructions facilitated the acquisition of exploratory skills. Although several previous studies investigated the development of exploratory thinking skills, no study examined the effectiveness of using SEPs of NGSS in developing exploratory thinking, which is the focus of the present research paper.

3.4 Hypothesis

There is a statistically significant difference at the level of ≤ 0.05 between the mean scores of the experimental groups (that studied exploratory activities using SEPs) and the control group (that studied in the traditional method) in the post-test of exploratory thinking and its sub-domains.

4. Methodology and Procedures

4.1 Method

The author utilized the quasi-experimental method based on the control and experimental groups.

4.2 Population and sampling

The population covered elementary students in Mecca. The sample comprised (64) randomly selected 4thgrade elementary female students from two classes in the Thirty-Four Elementary Schools in Mecca. They were distributed to the experimental and control groups for 2019/2020.

4.3 Materials and tools

A. A teacher's guide for the activities of the " Unit of Energy" was based on NGSS after reviewing the related literature, such as Almomani (2016), Shoman (2018), The National Academies Press (2012). It comprised an introduction, a list of SEPs, SEPs implementation principles and guidelines, performance indicators and expected learning outcomes, NGSS-based leaching strategies, evaluation methods, and gradual presentation of the activities in the light of SEPs according to the 5E learning cycle model.

The lessons' activities began with an introductory activity by invoking previous knowledge, discussing students, identifying their backgrounds, and writing their answers in the learning schedule. Then, the discovery stage included carrying out the activity either individually or collaboratively, followed by the interpretation stage in which the teacher discusses students in their findings, adjusts their error conceptions, and provides support to the groups that have achieved the most appropriate answer and the best forms of investigation and research. Finally, the enrichment and expansion stage included applying knowledge in new and more complex situations. At the end of each lesson, the evaluation process is conducted.

B. The student activity notebook included appropriate exploratory activities based on SEPs of NGSS among the 4th grade elementary students.

C. Preparing exploratory activities based on NGSS

To answer the first question, the author followed these steps:

- Reviewing the relevant literature, such as Almomani (2016), Shoman (2018), The National Academies Press (2012), The National Academies Press (2013), and Wilson et al. (2015).
- Choosing the "Unit of Energy" from the science course for the 4thgrade because it is one of the basic ideas of NGSS and in line with the national transformation program (202) and the Saudi Vision 2030, which is concerned with energy and its use, preserving, and diversifying sources.
- Determining a set of activities to achieve the objectives of the "Unit of Energy" after reviewing the scientific and educational resources and consulting several specialists in science instruction.
- Making a list of the expected learning performance after conducting exploratory activities based on SEPs of NGSS.
- Structuring the selected activities in the light of SEPs, including
- Asking verifiable questions and predicting results.
- Planning and carrying out explorations.
- Constructing interpretations and providing solutions.
- Obtaining information from sources, evaluation, and communication.
- -Engaging in an argument from evidence, comparing, and refining these arguments.
- -Using numbers to describe, measure, estimate, and organize data.
- -Using and designing models, such as diagrams, concrete forms, tables, and mathematical expressions.
- -Reading science and engineering texts, including tables, charts, diagrams, and websites to identify the main features of writing and the ability to produce written and illustrated texts using oral presentations.

The author came out with thirty-seven (37) exploratory activities based on SEPs distributed to the topics of the unit and explained in the student notebook and teacher's guide. They were presented to specialists in science curriculum and instruction, supervisors, and science teachers for the elementary stage. The required modifications were made to facilitate some activities to suit the age group.

D. Exploratory thinking test

The test aimed at ensuring the average acquisition of 4thgrade students of some exploratory thinking skills. It covered some exploration skills indicated as domains in the test, e.g. observation, interpretation, experiment, definition, conclusion, using numbers, classification, hypotheses, and impact of variables). Test items numbered (33) were phrased based on multiple-choice questions. Each one had four options and one score. Thus, the test score ranged (0-33). The test was presented to a group of reviewers to verify its validity. They made some modifications, including the deletion of five items and rephrasing some items. Thus, the final form comprised (28) items. After making the required modifications, the test was applied to (30) 4thgrade elementary female students in the Thirty-Four Elementary Schools outside the sample to calculate the following:

1- Test reliability

Test reliability was calculated by re-testing exploratory thinking to the same pilot sample after two weeks. The correlation between the degrees of the two tests was calculated using the Pearson correlation coefficient, as shown in table (1).

Table (1): Test reliability of exploratory thinking domains

Domains	Observation	Interpretation	Experiment	Definition	Conclusion
Reliability Coefficient	0.82	0.87	0.75	0.72	0.84
Significance	0.01	0.01	0.01	0.01	0.01
Domains	Using numbers	Classification	Hypotheses	Impact of variables	Total
Reliability coefficient	0.86	0.91	0.82	0.76	0.89
Significance	0.01	0.01	0.01	0.01	0.01

Table (1) illustrates that the test is highly reliable. Thus, it can be used to measure exploratory thinking domains.

2- Internal consistency

Pearson correlation coefficient was used to calculate the correlation between the scores of exploration

thinking domains and the total score, as shown in table (2).

Table (2): Internal consistency of exploratory thinking domains test

Domains	Observation	Interpretation	Experiment	Definition	Conclusion
Correlation coefficient	0.83	0.90	0.92	0.91	0.92
Significance	0.01	0.01	0.01	0.01	0.01
Domains	Using numbers	Classification	Hypotheses	Impact of variables	
Correlation coefficient	0.91	0.92	0.93	0.92	
Significance	0.01	0.01	0.01	0.01	

Table (2) indicates the significance of the Pearson correlation coefficient for domains' scores and the total score is high, indicating the internal consistency of the test.

3- Test time: The appropriate time for the test was calculated through the average time taken by each student, which was (45) minutes.

- The final form of the test

The test included a notebook for the test items, an instruction page, and a separate answer sheet. Then, the test was corrected. Exploratory thinking test consisted of (9) sub-domains, each domain has several items following by four options. Accordingly, students select the correct option and receive one degree for the correct answer and zero for the wrong one. The total score of the test is (28) degrees (Table 3).

Table (3): Features of the exploratory thinking test

Domains	Items	No. of items
Observation	21-22-24	3
Interpretation	1-8-13-15	4
Conclusion	5-16-18	3
Experiment	2-4-11	3
Definition	3-20-25	3
Using numbers	6-10	2
Classification	9-14-28	3
Hypotheses	7-17-19-23	4
Impact of variables	12-26- 27	3
Total	28	

- Field testing

The first stage: Preparing for the field test

1. Fulfilling the requirements for teaching the "Unit of Energy," including printing the student's activity notebook and teacher's guide and preparing the used materials and tools.
2. Meeting the experimental group science teacher and explaining the objectives and implementation of SEPs.
3. Creating a suitable classroom for experimental group students by providing a display screen and arranging seats to activate interaction.
4. Pre-testing exploratory thinking to the experimental and control groups students in the second semester of 2019/2020.
5. Verifying the equivalence between experimental and control groups by using a pre-test, correcting the answer sheets, and monitoring grades. T-test was used to compare the mean scores of the two groups in the research tools, as shown in Table (4):

Table (4): "T" value and significance level

Tool	Domains	Experimental group N=30		Control group N=30		"T" test	Significance
		Arithmetic mean	Standard deviation	Arithmetic mean	Standard deviation		
Exploratory thinking	Observation	0.875	0.421	0.91	0.39	0.308	Insignificant
	Interpretation	0.75	0.43	0.84	0.36	0.924	Insignificant
	Experiment	0.87	0.49	0.96	0.40	0.836	Insignificant
	Definition	0.61	0.43	0.43	0.25	1.39	Insignificant
	Conclusion	0.81	0.39	0.87	0.33	0.68	Insignificant
	Using numbers	0.56	0.50	0.50	0.43	0.46	Insignificant
	Classification	1.12	0.60	1.15	0.72	0.18	Insignificant
	Hypotheses	1.09	0.39	1.06	0.35	0.34	Insignificant
	Variables	6.66	1.69	6.53	1.29	0.33	Insignificant
	Total	13.31	3.39	13.06	2.58	0.33	Insignificant

Table (4) illustrates no differences between the mean scores of control and experimental groups in all research variables, indicating a high degree of equivalence.

The second stage: Carrying out the research experiment:

The "Unit of Energy" was taught to the experimental and control groups students, using exploratory activities and traditional method, respectively.

The third stage: post-test:

After completing the unit's teaching for experimental and control groups in the light of SEPs and the traditional method, the research tools were applied.

5.Results and Discussion

To test the validity of the research hypothesis, the "T" test was used for the differences between the experimental and control groups in the post-test of exploratory thinking, as shown in table (5).

Table (5): Means, standard deviations, "T" value, and the significance level of the post-test of exploratory thinking

Domains	Experimental group		Control group		"T" value	Significance
	Arithmetic mean	Standard deviation	Arithmetic mean	Standard deviation		
Observation	2.91	0.29	1.65	0.48	12.48	0.01
Interpretation	3.78	0.55	1.25	0.62	17.21	0.01
Experiment	3.00	0.00	1.28	0.58	16.73	0.01
Definition	2.96	0.17	1.53	0.67	11.71	0.01
Conclusion	2.91	0.29	1.53	0.51	13.24	0.01
Using numbers	1.84	0.36	1.46	0.67	2.76	0.01
Classification	2.93	0.24	1.62	0.49	13.50	0.01
Hypotheses	3.91	0.29	1.37	0.55	22.81	0.01
Impact of variables	2.87	0.33	0.71	0.45	21.51	0.01
Total	27.12	1.00	12.43	2.66	29.17	0.01

Table (5) illustrates significant differences between the mean scores of the experimental and control groups in the exploratory thinking domains and total score. "T" value was at the significance level of 0.01 favoring the experimental group.

To answer the second question, the effect size was calculated using Eta square, as shown in Table (6).

Table (6): Effect size of using exploratory activities based on ESPs of NGSS on the exploratory thinking of the experimental group

Domains	T" value"	T2	Freedom degree	Eta square	Significance
Observation	12.48	155.75	62	0.71	High
Interpretation	17.21	296.18	62	0.82	High
Experiment	16.73	279.89	62	0.81	High
Definition	11.71	137.12	62	0.68	High
Conclusion	13.24	175.29	62	0.73	High
Use number	2.76	7.61	62	0.10	Moderate
Classification	13.50	182.25	62	0.74	High
Hypotheses	22.81	520.29	62	0.89	High
Impact of variables	21.51	462.68	62	0.88	High
Total	29.17	850.88	62	0.93	High

Table (6) shows the high value of the Eta square, indicating the effectiveness of exploratory activities based on SEPs of NGSS at exploratory thinking and its various domains, except for the "using numbers" domain that was moderate.

Research findings of exploratory thinking test post-test indicated a high level of exploratory thinking for experimental group students who studied the activities of the "Unit of Energy" in the light of SEPs, unlike control group students who studied the same unit traditionally. Thus, the research findings are consistent with the results of Abu Laila (2015), Almomani (2016), Fick (2014), Kuhn et al. (2017), and Shoman (2018) that demonstrated the effectiveness of students' practice of SEPs based on NGSS in developing some variables and educational goals, in general, and thinking, in particular.

6.Recommendations

The author came up with a set of recommendations to employ SEPs in the educational process. For example, teacher preparation programs at the Colleges of Education should focus on preparing pre-service teachers in the light of NGSS and integrating them into teaching practices. Moreover, training programs are important for science teachers to identify the goals of NGSS and developing SEPs in the classrooms.

7.Conclusion

The present research paper demonstrated the effectiveness of exploratory activities based on SEPs of NGSS in developing exploratory thinking. Therefore, it is important to pay attention to NGSS, which represents the applied aspect of these standards and describes scientists' behaviors to engage in research and build models and theories about the natural world. Furthermore, exploratory activities based on SEPs enhance exploratory thinking among students.

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