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EFFECTIVENESS OF HANDS-ON CHEMISTRY EXPERIMENTS IN HIGH SCHOOL EDUCATION

Abstract. Practical laboratory work is essential to secondary school education, especially when it comes to chemistry and other related disciplines. This study assesses how well-developed skills, piqued scientific curiosity, and improved learning outcomes are all achieved through hands-on chemistry activities. In Kazakhstan, data was gathered from 75 students in the 10th and 11th grades of state general education schools through the use of a mixed-method technique that combined questionnaires and interviews. The majority of students confirmed that laboratory work helps with memorizing, improves enjoyment of chemistry, increases motivation, and improves general attitude towards the topic. The results show that these comments were overwhelmingly positive. Despite these advantages, problems including a lack of resources and equipment keep hindering thorough practical training. Ensuring fair access to high-quality education requires addressing these issues. This study highlights the importance of innovative teaching approaches and adequate resources to promote student engagement and success in science and technology.

Keywords: Hands-on laboratory work, Practical Chemistry, Chemistry

Introduction

Education in every country aims to develop literacy and advance science, marking a country's development. Science courses, particularly chemistry, are beneficial to students and society. Chemistry covers both theory and practice and for this reason, learning labs are designed in such a way that they support and enhance the process of finding and synthesizing ideas and materials (O'Connell, 2013). This means the laboratory must be well-equipped with the necessary equipment for effective learning. This study examines the effectiveness of practical chemistry experiments in secondary schools for skill-building and fostering scientific interest.

There is however a growing debate about the effectiveness and input of laboratory activities in fulfilling today's major purpose of science education, which is not to acquire scientific knowledge but to create it.

Despite this controversy, Schramm (2013) asserts that well-planned laboratory activities facilitate the development of a relevant learning environment intended to achieve this goal. The uniqueness of the laboratory work is demonstrated by the creation of a learning environment that favors both practical and mental activities. To (Osborn and Dillon, 2010), the experience obtained through experimental work provides a lasting impact on the minds of the students. This allows the teacher to inculcate various skills in the scientific process. Science laboratory plays an important role in helping us to change the learning environment where students, working in small groups, improve their understanding of scientific concepts, inquiry skills, and scientific attitude by investigating scientific phenomena (Hofstein & Lunetta, 2003).

Despite the debate surrounding the role of laboratory activities in contemporary science education, well-planned experiments are advocated for creating a conducive learning environment, promoting practical and mental engagement. However, in Kazakhstan, schools face challenges such as equipment shortages and limited resources, hindering comprehensive practical education. Rectifying this requires concerted efforts from educational authorities to ensure adequate resources for laboratory work.

Practical chemistry experiments enhance knowledge and cultivate skills vital for success in science and technology careers, such as data analysis and problem-solving. They catalyze students' interest in science, particularly in a world increasingly reliant on scientific and technological innovations. Improving practical chemistry education in secondary schools enhances education quality and fosters a competitive scientific community capable of addressing contemporary challenges. This paper delves into the efficacy of teaching chemistry through practical work settings.

Literature review

In modern education, the integration of technology into traditional teaching methods has become one of the most important trends, especially in science education.

The effectiveness of virtual laboratories compared to paper-based laboratories in developing practical skills in chemistry has attracted considerable interest. This very issue was addressed in a study by Manyilizu, M. C. (2023). The author discusses research on the effectiveness of virtual laboratory experiences compared to paper-based experiences in improving hands-on chemistry practical skills in Tanzanian secondary schools. It highlights the challenges faced due to the lack of physical laboratory resources and the benefits of virtual laboratories in enhancing student learning outcomes. The study emphasizes the importance of practical sessions in science education, especially in STEM subjects, and suggests that virtual laboratories can complement traditional hands-on labs, offering flexibility, cost-effectiveness, and enhanced learning opportunities for students.

These studies provide valuable insights into the effectiveness of different teaching methodologies, especially in chemistry education, shedding light on the potential benefits and challenges of hands-on experience. For instance, Iyamuremye, A., Nsabayeze, E., Ngendabanga, C., & Hagenimana, F. (2023) analyzed the impact of hands-on chemistry activities on students' academic performance, engagement, and experience. For this purpose, a descriptive method and a mixed research design including a chemistry test and a survey with a variety of questions were used.

The findings indicated a high level of student engagement and positive experiences related to practical chemistry classes. The intervention resulted in statistically significant changes in students' academic performance. However, no statistically significant differences were found in the study results based on gender or type of student's school.

The study also identified certain challenges to effective hands-on chemistry classes, including lack of chemical reagents, limited laboratory equipment, limited laboratory space, and insufficient time allocation for hands-on activities. The authors suggest providing additional equipment, utilizing local resources, and increasing laboratory time as possible solutions.

An equally relevant study was also conducted by Adkins, D. G. (2020) in which she investigates the effect of laboratory experiments on students' attitudes and interest in science through various tests and analyses. The results indicate positive outcomes of hands-on activities and potential problems with computer simulations. The study aims to increase understanding of science education and the importance of hands-on experience. The study highlights the importance of hands-on learning in developing positive attitudes and interest in science in students. The study examines the definition of science, scientific hypotheses, and theories, stressing the importance of empirical evidence in scientific inquiry and the development of valid explanations.

Also, Hensen, C., & Barbera, J. (2019) explore the role of hands-on and simulation experiments in improving students' understanding of physical chemistry concepts and demonstrate a significant improvement in student performance when using these methods. The article emphasizes the importance of incorporating these active learning strategies into the teaching of chemistry to promote better student engagement and understanding of the material. The study also highlights the positive impact of peer collaboration and meaningful discussions during experiments, leading to improved learning outcomes in physical chemistry courses. Furthermore, the article highlights the potential of these interactive approaches to develop students' critical thinking skills and deeper conceptual understanding, which ultimately contributes to their success in chemistry.

According to this literature review, our article aims to evaluate the effectiveness of hands-on experiments in high school chemistry, in particular, to investigate their impact on skill development, student interest, and overall learning outcomes.

The main research question is: What is the effectiveness of hands-on chemistry experiments in secondary school to develop skills, increase interest, and improve overall learning outcomes in the subject, especially when dealing with problems such as lack of equipment and limited resources?

Methodology

3.1 Research methods

This research uses a mixed method combining questionnaires and interviews. The survey will be administered to secondary school students of secondary schools in Kazakhstan to assess the current status of practical experiments in chemistry. Survey will be conducted with 10th and 11th-grade

students. The collected data will be analyzed to evaluate the effectiveness of practical chemistry experiments in secondary schools and recommend their improvement.

3.2 Sampling

The study involved 75 students of 10th and 11th grades of state general education schools in Kazakhstan. Using a mixed method combining questionnaires and interviews, the study evaluates the effectiveness of practical experiments in chemistry. The data obtained will serve as a basis for recommendations to improve the effectiveness of these experiments in secondary schools. Ethical standards were followed during the data collection process to ensure the confidentiality and informed consent of the participants.

3.3 Data collection

In research, surveys were conducted to assess the effectiveness of practical chemistry experiments. In addition, individual students were interviewed to gain a deeper understanding of their experiences. The survey questions were about laboratory and practical work in chemistry, and the interviews included the process of learning, and engaging with the subject matter.

3.4 Data analysis

During data acquisition, the data was analyzed to obtain the result. The table below shows the questions and answers of students in percent depending on the response option.

Result

If we analyze the statistics obtained during the survey and interviews, we get the following results:

93,33% answered "yes" to the question - Do you think that laboratory work helps to memorize the material better than theoretical classes only?

82,67% answered "yes" to the question - Do chemical experiments make learning chemistry more fun?

76% answered "yes" to the question - Do chemical experiments influence your motivation to study chemistry and your general attitude towards the subject?

88% answered "yes" to the question - Do chemical experiments influence your memorization and application of theoretical knowledge of the subject?

Questions	Answers 75			
1. How often do you conduct chemical experiments in chemistry class?	Once a week (6,67%) 5	Once a month (16%) 12	Rarely (52%) 39	Almost never (25,33%) 19

2. Do you think that laboratory work helps you to memorize the material better than theoretical study alone?	Yes (93,33%) 70		No (6,67%) 5	
3. What difficulties do you experience when performing chemical experiments at school?	Lack of experience (25,33%) 19	Lack of practical work (34,67%) 26	No basic knowledge (22,67%) 17	I don't find it difficult (17,33%) 13
4. Do you feel that doing chemistry experiments at school helps you to be better prepared for future career opportunities in chemistry?	Yes (70,67%) 53		No (29,33%) 22	
5. How would you rate your overall motivation and interest in learning chemistry after doing the hands-on activities? (From 25 to 100)	25 (9,33%) 7	50 (18,67%) 14	75 (34,67%) 26	100 (37,33%) 28
6. Do you think that doing chemistry experiments helps you better understand the role of chemistry in everyday life?	Yes (49,33%) 37		No (50,67%) 38	
7. Do chemical experiments make learning chemistry more fun?	Yes (82,67%) 62		No (17,33%) 13	
8. Do chemical experiments affect your motivation to learn chemistry and your general	Yes (76%) 57		No (24%)18	

attitude towards the subject?		
9. Does conducting chemical experiments affect your memorization and application of theoretical knowledge of the subject?	Yes (88%) 66	No (12%) 9

According to the obtained data, we can say that laboratory and practical works are interesting and exciting, which increases the involvement in the subject and helps to remember the principles of action and theory of chemistry, and this contributes to good memorization of the material and the program. To all this can also be added an increase in motivation to learn chemistry and a general attitude towards the subject. In parallel with these data, we also learned that most schools do not organize this kind of class for various reasons. The most popular ones are:

- No necessary equipment
- Shortage or lack of chemical reagents
- No provision for laboratory work

During the interviews, we also found that without practical work, the process of learning chemistry is still not very interesting, and teachers are still monotonous in the teaching process, and innovations in teaching are not changing in line with technological advances. And conducting lessons using laboratory work was something new to them and students felt clarity and interest in the subject.

Conclusion

In summary, this study emphasizes the crucial role of practical chemistry experiments in the secondary school learning process. The results confirm that laboratory work significantly enhances learning: the vast majority of students report that it promotes memorization, makes chemistry more interesting, increases motivation, and improves their overall attitude toward the subject. However, despite the obvious benefits, the study has identified serious problems preventing the widespread adoption of hands-on experiments, including lack of equipment and resource constraints. Addressing these obstacles is critical to ensuring equitable access to quality education. In addition, the study highlights the need for innovative teaching approaches to keep pace with technological advances and promote student engagement. By prioritizing hands-on chemistry learning and overcoming existing barriers, teachers can create a dynamic learning environment that fosters scientific curiosity and equips students with the necessary skills to succeed in science and technology.

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ISSUES OF THE INTEGRATIVE STEM LESSON FOR SCHOOL

Abstract. This study was designed to determine the level of STEM integration, particularly in chemistry lessons, and what difficulties/benefits this action may have. The study included 18 articles by different authors on different topics, but with one goal - STEM integration. The result showed that out of 18 articles, 16 partially contain the idea of integrating STEM methodology. In particular, 7 articles were designed to integrate STEM in high school. the rest were intended for teachers in general. None of the articles were intended for elementary school.

Keywords: STEM education, integrated STEM in school

Introduction

In modern education, there is a gap between traditional teaching methods and the needs of modern society. As the study shows, many schools and educational institutions still adhere to the lecture approach, ignoring the principles of active and practical learning. (Felder, R. M., & Brent, R. 2024). However, in a dynamically changing world, where the skills of applying knowledge in practice and solving real problems are in demand, standard teaching methods become ineffective. In this context, stem education plays a key role, combining science, technology, engineering and mathematics into a whole educational process. This research is aimed at developing software for teaching the basics to school,