The Effects of MyNanoria Mobile Applications on Students' Understanding of Nanotechnology in Chemistry Learning

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Abstract
This research investigates the effect of MyNanoria mobile applications in enhancing students' understanding of nanotechnologies in chemistry. This study addresses the problem of insufficient comprehension on complex nanotechnology concepts among chemistry students. It is important to understand about nanotechnology because it will affect the ability to apply knowledge in practical scenarios, including industrial fields. Employing a quasi-experimental design with a one-group pre-test and post-test approach, thirteen purposively selected students participated in the study. Data collection involved pre and post-tests using a set of seventeen multiple-choice questions to assess students' knowledge across four areas which consists of nanotechnology, nanomaterials, nanomedicine, and cancer. Statistical analysis utilizing SPSS 27.0 included descriptive statistics, normality tests, and a paired sample t-test. Findings revealed a significant improvement in post-test scores ($M = 14.3846$) compared to pre-test scores ($M = 7.6923$), with a smaller standard deviation and a highly significant p-value (< 0.001). This indicates the effectiveness of MyNanoria mobile applications in enhancing students' comprehension of nanotechnology in chemistry. The considerable effect size ($r^2 = 0.8889$) underscores the practical significance of this improvement. Consequently, this study supports the use of mobile applications like MyNanoria as valuable tools in teaching complex scientific concepts, which emphasize the need for ongoing exploration and development of technology-driven educational strategies to optimize learning outcomes in the field of nanotechnology.

Keywords: Nanotechnology, MyNanoria, Chemistry Education, Effectiveness and Mobile Application.

Introduction

Chemistry Teaching and Learning Technology

Technology has always played a vital role in our daily existence. Utilizing scientific innovations, regulations, principles, and procedures in various life domains falls within the realm of chemistry teaching and learning technology. Many types of technologies exist, including educational technology. Technology always maintains a reciprocal relationship with chemistry education. It begun to infiltrate the realm of chemistry education by transforming the way students receive knowledge and thus technology is expected to enhance the landscape of chemistry learning by making it more costeffective and readily available (Haleem *et al*., 2022). With the invention of new technologies, students managed to better understand course content and thus able to achieve excellent results in Chemistry (Roy, 2019). A statement by George Couros asserts that exceptional educators cannot be substituted by technology, but when technology is skilfully wielded by exceptional teachers, it can bring about significant change (Roy, 2019).

In the contemporary educational environment, traditional classroom instruction in chemistry often falls short in providing an immediate learning experience, swift evaluation, and high levels of engagement. This gap is effectively addressed by digital learning tools and technology, offering a more dynamic and interactive chemistry learning environment (Zhang, 2022). The rapid pace of technological advancement has rendered traditional Chemistry educational methods insufficient in unlocking the full potential of both Chemistry learners and educators. This technological evolution aims to create a learning environment where information, knowledge, and immediate feedback are easily accessible, fostering greater engagement and interest among Chemistry learners (Haleem *et al.,* 2022).

Traditional education in Chemistry is replaced by digital education

Traditional education in Chemistry which is the imparting of knowledge through a teacher-centered approach, have been a longstanding practice (Bo *et al.,* 2022). In the traditional educational landscape, institutions, printed materials, and educators played pivotal roles, with students enrolling in schools to access both teachers and library resources (Yarychev & Mentsiev, 2020). The traditional teaching and learning paradigm positioned the teacher at the forefront of the classroom, relying heavily on textbooks, prioritizing fundamental skills, and assessing learning based on the time spent studying rather than time spent in lectures (Serroukh & Serroukh, 2022).

This traditional model, prevalent before the digital age, had limitations in providing widespread access to knowledge and education in Chemistry. Access to up-to-date information was constrained, leaving many uninformed about global events (Yarychev & Mentsiev, 2020). The advent of the digital age marked a significant shift from traditional to digital education in Chemistry. Technological advancements have vastly improved the accessibility of Chemistry education, allowing information to travel rapidly across the globe (Yarychev & Mentsiev, 2020). In the contemporary teaching approach in Chemistry, learners benefit from a more social and interactive environment, promoting independence in the learning process (Serroukh & Serroukh, 2022). In this context, MyNanoria Application, a mobile application, was developed to improve understanding of nanotechnology among students during chemistry learning process.

MyNanoria Application for Chemistry Teaching and Learning Process

MyNanoria was developed by initially designing suitable content, compiling information, and creating the app using the Unity platform specifically for the Android operating system (Nik Malek *et al.,* 2024). MyNanoria provides users with readily available knowledge about nanotechnology's concepts, methods, and applications as an interactive educational tool. The app covers specific facets of nanotechnology, nanomedicine, nanomaterials, and cancer, and includes definitions for particular keywords. The creation of this app required consulting and validation by subject-matter specialists, such as chemists, biologists, and medical scientists (Nik Malek *et al.,* 2024). However, the development of MyNanoria posed challenges due to the multidisciplinary nature of nanotechnology, which emphasizes scientific understanding, while the intended users may have little to no prior knowledge of the subject. With the MyNanoria app, the knowledge and awareness gap between science and students is bridged, enabling students to fully appreciate potential of nanotechnology in healthcare.

The app features an intuitive user interface designed to facilitate easy navigation and engagement. Interactive modules allow students to explore complex concepts through simulations, quizzes, and multimedia content (Nik Malek *et al.,* 2024). For example, students can manipulate virtual nanoparticles to observe their behavior in different environments, helping to bridge the gap between theoretical knowledge and practical application. The app also includes a glossary of key terms and concepts, making it a comprehensive educational resource. To support teachers in integrating MyNanoria into their lessons, the app includes detailed guides and lesson plans aligned with the chemistry curriculum (Nik Malek *et al.,* 2024). It is important for teachers to be encouraged to use the app as a supplementary tool, allowing students to work independently or in groups to explore nanotechnology topics at their own pace which benefits students during their chemistry learning process.

The Importance of Technology in Chemistry Teaching and Learning Process

One of the paramount advantages of technology in chemistry education is its ability to foster interactive and immersive learning experiences. Virtual laboratories, simulation software, and interactive apps provide students with the opportunity to conduct experiments in a risk-free and controlled digital environment. These tools allow learners to manipulate variables, observe reactions, and comprehend complex chemical phenomena, thereby bridging the gap between theory and practical application (Elmoazen *et al.,* 2023).

The integration of technology has democratized access to quality chemistry education. Online resources, e-books, video lectures, and educational websites break down geographical barriers, providing students with diverse learning materials at their fingertips. Additionally, technology facilitates flexible learning schedules, allowing students to access course materials and lectures at their own pace, catering to individual learning styles and preferences (Wu *et al.,* 2021).

Chemistry often involves abstract theories and intricate molecular structures that can be challenging to visualize. Technology comes to the rescue by offering sophisticated visualization tools that enable students to grasp these abstract concepts more intuitively (Almesh & Meirmanova, 2023). Molecular modeling software and 3D animations aid in visualizing molecular structures, bonding arrangements, and chemical reactions, empowering students to explore and understand the microscopic world of chemistry with unprecedented clarity.

In the present age of globalization, the educational landscape has been revolutionized by digital tools, with MyNanoria emerging as a standout mobile application facilitating the seamless learning of nanotechnology in chemistry. Developed by dedicated lecturers at a public university, MyNanoria transcends conventional boundaries by encompassing four crucial fields: Nanotechnology, Medicine, Nanomedicine, and Cancer. This innovative application serves as a comprehensive educational hub, offering students a user-friendly platform to easily delve into the intricate realms of nanotechnology when implemented during chemistry learning process.

Implementation of Nanotechnology in Chemistry
Nanotechnology, a modern field combining science, engineering, and technology, has transformed many industries, notably changing how chemistry and medicine work. In the realm of chemistry, its integration has revolutionized the way we perceive and manipulate matter. Application of nanotechnology in Chemistry is so important as it involved in Form 4 syllabus under the subtopic “Development in Chemistry Field and Its Importance in Daily Life”. While the Form 5 students learn nanotechnology in chapter 5 entitled “Consumer and Industrial Chemistry”.

Nanotechnology involves the manipulation of matter on a molecular and atomic scale, creating materials, devices, and systems with novel properties and functionalities (Bayda *et al*., 2020). In the realm of chemistry, this precision engineering at the nanoscale enables the synthesis of nanoparticles, nanomaterials, and nanostructures with remarkable characteristics, providing a platform for innovative applications in medicine.

One of the most significant areas where nanotechnology has made considerable strides is in nanomedicine. By leveraging nanoscale materials, scientists and medical researchers have developed advanced drug delivery systems that offer improved pharmacokinetics and targeted therapeutic outcomes (Bayda *et al.,* 2020). Nanoparticles, due to their small size and unique properties, can evade biological barriers, penetrate tissues, and deliver therapeutic agents selectively to diseased cells, minimizing collateral damage to healthy tissues.

In the context of cancer treatment, nanotechnology has emerged as a beacon of hope. Nanomedicine presents a paradigm shift in oncology by offering targeted drug delivery, enhancing treatment efficacy while reducing adverse effects (Jin *et al.,* 2020). Nanoparticles can be engineered to carry chemotherapeutic drugs, targeting specific cancer cells or tumors through surface modifications or functionalization. This precision targeting reduces systemic toxicity and enhances the concentration of drugs at the tumor site, augmenting the therapeutic effect.

Constructivism Learning Theory
Constructivism Learning Theory is a foundational element in modern educational practices, emphasizing the active role of learners in constructing their own understanding and knowledge through experiences and interactions with their environment (Ponde & Bharanthi, 2020). This theory posits that learning is an active, contextualized process of constructing knowledge rather than passively receiving information. Rooted in the works of educational theorists such as Jean Piaget and Lev Vygotsky, constructivism underscores the importance of cognitive processes and social interactions in the development of understanding (Sharma & Shukla, 2023).

In the context of Chemistry education, constructivism provides a robust framework for enhancing student engagement and comprehension. The traditional teacher-centered approach often falls short in addressing individual learning needs and fostering deep understanding, particularly in complex and abstract subjects like

Chemistry. Constructivism, however, advocates for a learner-centered approach where students actively participate in the learning process, thereby making sense of new information in the context of their prior knowledge and experiences (Chand, 2024).

The integration of technology in Chemistry education further amplifies the principles of constructivist learning. Digital tools and interactive platforms offer dynamic and immersive learning experiences, aligning perfectly with constructivist ideals (Taber, 2017). For instance, virtual laboratories, simulation software, and interactive applications provide students with opportunities to experiment, manipulate variables, and observe chemical reactions in a controlled digital environment. These technologies not only bridge the gap between theoretical concepts and practical application but also cater to diverse learning styles and paces (Taber, 2017).

The MyNanoria mobile application exemplifies the synergy between constructivism and technological innovation in education. By offering interactive modules on nanotechnology, medicine, and cancer, MyNanoria engages students in a hands-on learning experience that promotes exploration and critical thinking. This approach aligns with the 5E learning strategy—Engage, Explore, Explain, Elaborate, and Evaluate—which is grounded in constructivist theory. Through this model, students are encouraged to actively construct their knowledge, connect new information with existing cognitive structures, and apply their understanding to real-world scenarios (Chand, 2024).

The constructivist learning theory provides a theoretical underpinning for the study of MyNanoria's impact on students' understanding of nanotechnology in Chemistry. By leveraging the interactive capabilities of digital technology and adhering to constructivist principles, this study aims to create a learning environment that fosters deeper engagement, personalized learning experiences, and enhanced comprehension of complex scientific concepts.

Problem Statement

Use of technology in chemistry teaching and learning process is necessarily to be implemented as technology offers interactive tools and platforms that encourage active participation among students. It also provides students with access to a wealth of information beyond textbook. They can explore current research, case studies, and real-world applications of chemistry, fostering a deeper understanding of the subject.
Nanotechnology which is defined as the branch of technology that deals with dimensions and tolerances of less than 100 nanometres, especially the manipulation of individual atoms and molecules, presents groundbreaking opportunities for students to explore the implementations of nanotechnologies in Chemistry including topics nanotechnology, nonamaterials, nanomedicine and cancer.

However, the complexities of nanotechnology often pose a barrier to understanding, especially for students. There exists a disparity between the advancements of nanotechnology in Chemistry and their accessibility to students. While the importance of nanotechnology in Chemistry is vast, there is a gap in effectively disseminating this knowledge to a wider audience, including students. Secondary school students' knowledge remains basic in topic of nanotechnology in Chemistry.

In this context, mobile applications could serve as education tools to simplify and present this intricate information in an accessible and engaging manner. MyNanoria application, a mobile application technology, was developed to address these very challenges. This application aims to make nanotechnology more approachable and understandable for students by providing interactive and user-friendly content. With this application, students managed to grasp and understand deeper knowledge in the topic of nanotechnology in chemistry which prepare them for further studies.

Research Objective:
To identify the effects of using MyNanoria mobile applications on students' understanding of the application of nanotechnology in Chemistry.

Research Question:
What is the effects of using MyNanoria mobile applications on students' understanding of the application of nanotechnology in Chemistry?

Hypothesis:
$H_{0:}$ There is no significant difference between the pre-test and post-test in the application of nanotechnology in Chemistry using MyNanoria mobile applications.

Methodology

Research Design
This study focuses on assessing the effect of an intervention, specifically the use of MyNanoria mobile applications, on students' knowledge of nanotechnology, nanomaterials, nanomedicine, and cancer. The quasi-experimental design of one group pre-test and post-test was used for the administration of the pre-test, intervention with the MyNanoria apps, and also the post-test.

Research Procedure
The 5E learning strategies, which consist of engagement, exploration, explanation, elaboration and evaluation was used in this study and the flow of experimental activities was explained in Figure 1. The induction set of engagement started with introduction of teachers and ice breaking with the students. Students were then required to scan a provided QR Code, which led them to the platform of Padlet. Inside the Padlet, there were the link of pre-test, post-test and MyNanoria apps. By using Padlet, it makes them easier to access all the link provided. After that, pre-test was conducted to identify students' initial knowledge on nanotechnologies in chemistry. Ten minutes was given for students to answer the pre-test questions.

Next, teachers brief on the MyNanoria which act as an educational mobile application that designed to enhance students' understanding of nanotechnology, nanomaterials, nanomedicine, and cancer through interactive content and quizzes. The app includes detailed explanations, diagrams, and real-world applications of these topics, making complex concepts more accessible. At the same time, students need to install the apps through their own mobile phone using the link given in the Padlet.

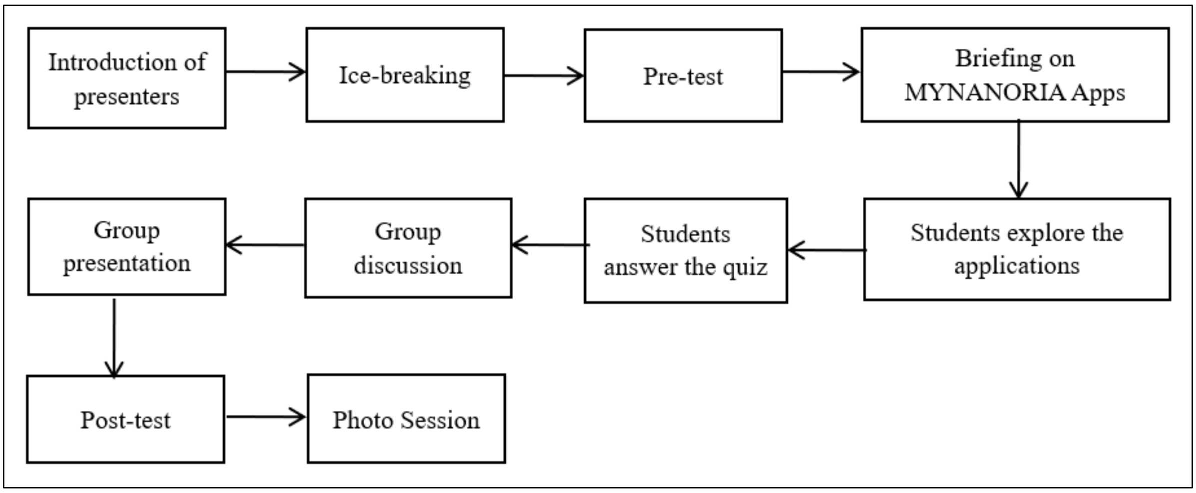

Figure 1: The Flow of Experimental Activities

In the exploration phase, students explored the contents and answered the quizzes in MyNanoria apps that covered of four topics (nanotechnology, nanomaterials, nanomedicine, and cancer). At the third phase, which is explanation phase, teacher explained briefly about the themes in the apps, which also covering nanotechnology, nanomaterial, nanomedicine and cancer.

In the elaboration phase, students were divided into four groups with four different themes: i) Nanotechnology, ii) Nanomaterial, iii) Nanomedicine, iv) Cancer. All group were given 15 minutes to discuss and 3 to 5 minutes to present. The group discussion focused on exploring detailed aspects of their assigned theme. They used MyNanoria apps to gather information and discuss about the relevance and application of the apps. The presentations were conducted to reinforce their understanding and allowed for peer learning through the Q&A sessions. At the last phase, which is evaluation, a post-test with the same questions as the pre-test questions were provided for students to answer through Google Form. The answers scripts were reviewed after the test for analysing using software SPSS 27.0.

Population and Sample

The study focused on students enrolled in the first year of the Bachelor of Chemistry Education program at a university located in Johor Bharu. Form 5 students could not be included in the sample because they are involved with examination of Sijil Pelajaran Malaysia (SPM). According to Eras 2.0 (2020), students in examination classes cannot be included in data collection for any research. From this population, a sample of thirteen students was purposefully selected to participate in the research study. The selected sample was considered sufficient to provide meaningful insights into the effectiveness of the research intervention within the specific academic context of chemistry education at the university in Johor Bahru.

Research Instrument

The instrument used in this study consist of seventeen multiple-choice questions prepared by the researchers. The questions were categorized into four sections namely nanotechnology, nanomaterials, nanomedicine, and cancer. These questions aim to assess students' knowledge of the specified topics. For example, in the nanotechnology section, the questions ask about definition of prefix nano, range of nanoparticles, main purpose of invention of nanotechnology, command fields of nanoparticles used, and correct statement about nanotechnology.

For nanomaterial sections, the questions ask about the total of classifications in nanomaterials, usage of nanomaterials, an example of a zero-dimensional (OD) nanomaterial, and the statement about the consideration of liposome as three-dimensional (3D) nanomaterial. In nanomedicine section, the example of questions included the usage of fullerene as a treatment for several diseases and the type of material used in nanomedicine. Last section which is a cancer, the example of question are the characteristics of cancer cell, and the factor that caused the cancer.

Data Collection and Analysis

For data collection, a pre-test and post-test method was employed, requiring a total time commitment of two hours. The pre-test served as an initial assessment of students' knowledge, followed by the post-test administered after the intervention. The comprehensive data analysis was conducted using SPSS 27, incorporating both descriptive and inferential statistics.

The descriptive statistic was interpretate for students' overall achievement, employing the mean scores and standard deviations. Additionally, the study assessed the significance difference between pre-test and post-test results through the inferential statistic, which is a Paired Sample t-test. These analytical methods were crucial in gauging the effect of the intervention in enhancing students' understanding of nanotechnology, nanomaterials, nanomedicine, and cancer.

The two-hour timeframe allowed for a thorough examination of the students' performance before and after the intervention, contributing valuable insights to the research study. Some students faced challenges in understanding the advanced concepts of nanotechnology and its applications. These difficulties were addressed through additional explanations and visual within the MyNanoria apps, which helped to clarify the complex topics.

Results and Discussion

The study investigates the effect of MyNanoria mobile applications on students' understanding which focus on pretest and post-test variables. It encompasses a dataset of 13 valid observations. Figure 2 shows the histogram of the individual scores pre-test, spanning from a minimum of 5.00 to a maximum of 11.00. It reflected the initial diversity in students' understanding before the intervention with MyNanoria mobile applications. This diversity can be attributed to varying levels of prior knowledge and engagement in traditional learning methods.

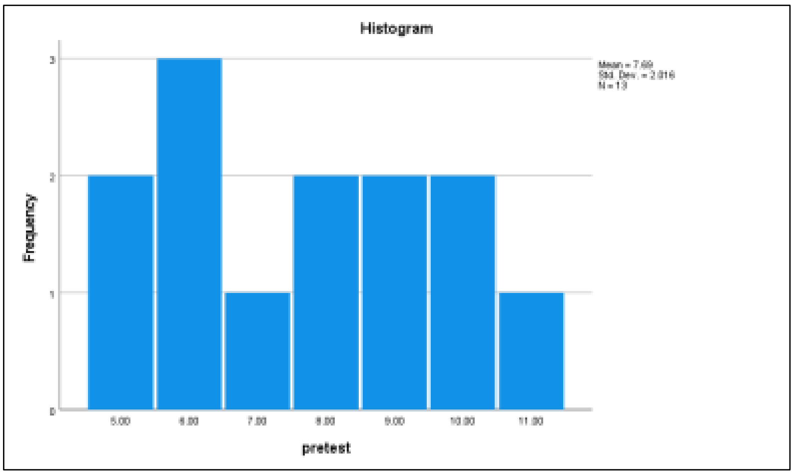

Figure 2: Histogram of Pre-Test

Figure 3 shows the histogram of the post-test variable which present the score from minimum of 13.00 to a maximum of 17.00. In the context of the 5E learning strategies, the aims were to create a compatible learning experience that addresses individual differences and promotes a deeper understanding of complex concepts in nanotechnology. Therefore, the observed data in post-test scores aligns with the goals of this 5E learning strategy.

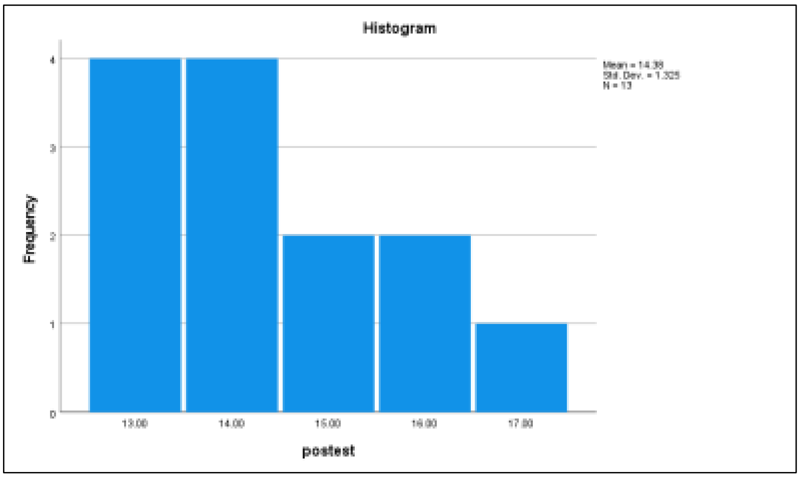

Figure 3: Histogram of Post-Test

Table 1 presents descriptive statistics for the pre-test and post-test variables. The pre-test has a mean score of 7.692, a standard deviation of 2.016, and a variance of 4.064. In contrast, the post-test has a mean score of 14.385, a standard deviation of 1.325, and a variance of 1.756. The pre-test's higher standard deviation implies a broader spread of scores and a more diverse range of initial performance levels. The post-test, with its lower standard deviation, indicates a more homogeneous distribution and a degree of consistency in performance following the intervention (Sookoo-Singh & Boisselle, 2018). This improvement reflects the impact of the 5E learning strategy to foster a more comprehensive and integrated understanding of the nanotechnology in chemistry education.

Table 1: Descriptive Statistics for Pre and Post test.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
pretest	13	5.00	11.00	7.6923	2.01596	4.064
postest	13	13.00	17.00	14.3846	1.32530	1.756
Valid N (listwise)	13					

Table 2 focuses on the results of tests of normality conducted on two variables, namely pretest and post-test. The normality of these variables was assessed using two distinct tests, the Kolmogorov-Smirnov test and the Shapiro-Wilk test. The outcomes of these tests provide valuable insights into the distributional characteristics of the data. However, this study focusses on Shapiro-Wilk test because the sample used is less than 50 (Yap & Sim, 2011). The Shapiro-Wilk test produced a significance level of 0.352 for pre-test while a significance level of post-test is 0.080.

Table 2: Normality test for Pre and Post Test.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
pretest	.184	13	.200*	.931	13	.352
postest	.230	13	.059	.884	13	.080

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on Figure 4, the Normal Q-Q plot of the variable pre-test shows that the observed values align reasonably well with the diagonal line, indicating that the data may follow a normal distribution. The associated Shapiro-Wilk test yields a p-value of 0.352, which mean the data higher than the conventional significance level of 0.05. So, the normality of this pre-test can be accepted.

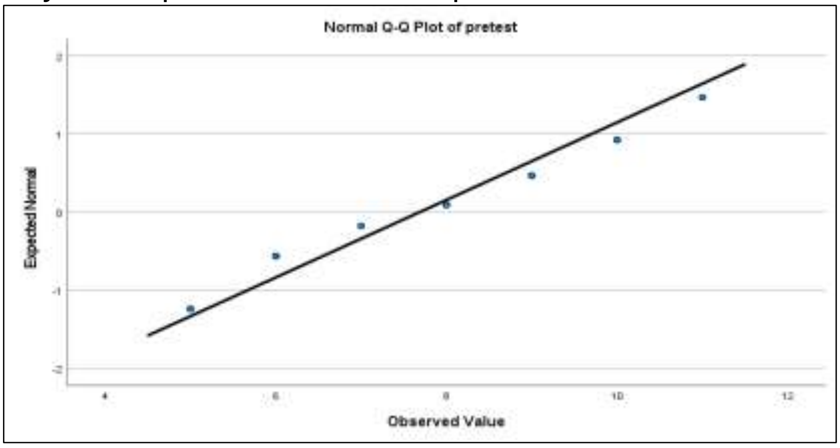

Figure 4: Normality Plot of Pre-test

Figure 5 provided Normal Q-Q plot of the variable post-test which shows that the observed values align reasonably well with the diagonal line, indicating potential normality. The plot indicates that the points are randomly scattered around the horizontal line at zero, suggesting that the data may follow a normal distribution. The associated Shapiro-Wilk test yields a p-value of 0.080, which mean the data higher than the conventional significance level of 0.05. So, the normality of this post-test can be accepted. The application of the 5E learning strategy is a prove in these analyses, as the structured approach contributes to the normalization and improvement of students' performance.

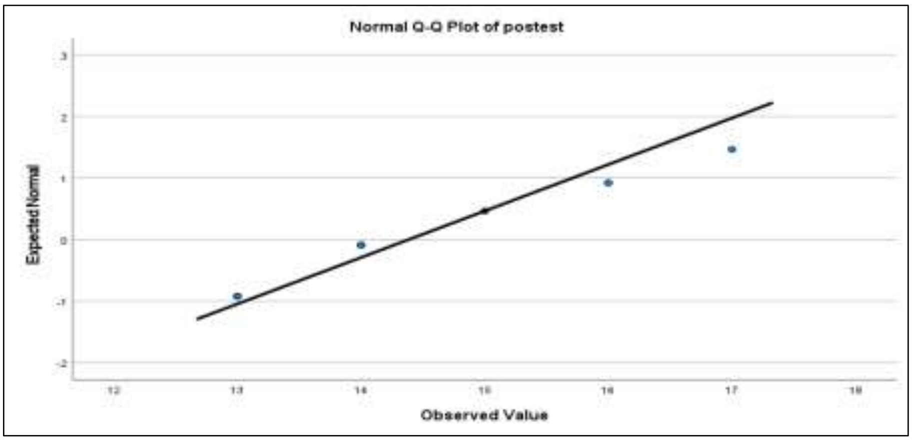

Figure 5: Normality Plot of Post-test

Table 3 shows the result of paired sample t-test for the pre-test and post-test. The application of nanotechnology in chemistry using MyNanoria mobile applications can improve pre-test compared to post-test result by an average of mean, M = - 6.6923, with SD= 2.46254, t (13) = -9.799, p (0.001) < 0.05 and r2 = 0.8889. Therefore, there is enough evidence to reject the null hypothesis. By systematically employing 5E model, the students not only gained knowledge but also retained and applied it effectively. So, MyNanoria mobile applications has been shown to be effective in enhancing students' understanding on nanotechnology application in chemistry education.

Table 3: Paired Samples t-test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	pretest - postest	-6.69231	2.46254	.68299	-8.18041	-5.20421	-9.799	12	<.001

This study revealed a significant improvement in students' performance from pre-test to post-test. Here, it indicates a notable positive impact on their comprehension of nanotechnology's application in chemistry. Plus, the statistical analyses confirmed a consistent and substantial enhancement in students' knowledge with a support by a smaller standard deviation and a significant p-value which is less than 0.001. The considerable effect size which is equal to 0.8889 further emphasizes the practical significance of this improvement as well as highlighting the efficacy of incorporating mobile applications like MyNanoria to facilitate learning in the field of nanotechnology.

Generally, to enhance educational outcomes further, it's recommended to explore diverse educational apps tailored for complex scientific concepts that can support educators with ongoing training in utilizing technology effectively (Azis & Cantafio, 2023). Besides, embracing interactive platforms and personalized tools also can create engaging learning environments, catering to diverse learning styles and fostering inclusivity (Chifamba, 2022). This recommendation can maximize technology's impact on education through continual research and development efforts. However, it is important to acknowledge a potential conflict of interest in this research regarding sample selection. If the sample of students was not randomly selected or if there was a bias in selecting students who were more likely to benefit from the app, this could skew the results and conclusions. To address this, future studies should ensure random and unbiased sample selection to validate the findings and enhance the generalizability of the results.

Conclusion

In conclusion, the utilization of MyNanoria mobile applications in teaching nanotechnology in chemistry has proven to be highly effective in enhancing students' understanding.

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