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Impact of Integrating History of Science into Life Science Teaching of Viruses on Students' Comprehension of Microbiology Concepts

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Abstract
Understanding microbiology, especially viruses, is pivotal in life science education, shaping students' comprehension of scientific principles. Incorporating the history of science into life science lessons, particularly focusing on viruses, holds immense importance in enhancing students' understanding of microbiology concepts in schools situated in rural areas like Kwa-Dlagazwa, South Africa. The significance lies in the scarcity of educational resources in such regions, making it crucial to employ innovative yet cost-effective methods to enrich learning experiences. This study sets out to create a more welcoming and captivating environment for science education, aiming to make the complexities of virology and microbiology more relatable and engaging for learners. The study was guided by two hypotheses and a sample of fifty (50) 10th-grade life science learners and ten (10) life science teachers, selected through simple random techniques from public schools in Kwa-Dlangezwa. Data collection utilized class tests and closed-ended questionnaires, which were analyzed using SPSS version 13. The results indicated that the null hypothesis (H0) for the pre-test was not rejected, with $p > 0.05$ in both instances. This suggests that there is no significant difference in students' understanding of microbiology concepts between those exposed to life science teaching of viruses with the integration of the history of science and those taught using traditional methods at the pre-test stage. As a recommendation, it is proposed that students be introduced to the captivating life stories of scientists who delved into the unexplored realms of virology, enhancing their engagement with the subject matter.

Keywords: History of Science, Integrating, Life Science Teaching, Viruses, Microbiology Concepts, and South Africa.

INTRODUCTION

The significance of life science education in shaping students' understanding of microbiology, particularly in relation to viruses, cannot be overstated. As scientific knowledge advances, there is a growing recognition of the value of integrating historical perspectives into science education [1]. Incorporating historical context not only enhances the learning experience but also provides students with a more comprehensive grasp of complex concepts [2]. In the realm of life science education, the study of viruses is particularly captivating yet intricate. Teaching about viruses extends beyond conveying facts and mechanisms; it involves instilling a deep understanding of their historical significance and the evolutionary trajectory of scientific understanding. This research aims to explore the impact of integrating the history of science into life science teaching, with a specific focus on viruses, and its influence on students' comprehension of microbiology concepts.

Over the years, there has been a call for the transformative potential of incorporating historical perspectives into science education, highlighting the depth and contextualization it brings to complex scientific concepts [3, 4]. While this approach has shown positive effects in various scientific domains, there is a noticeable research gap concerning how such historical integration affects the comprehension of microbiology concepts, especially with a focus on viruses. Existing literature primarily concentrates on broader scientific principles, leaving a void in our understanding of the specific dynamics and benefits within the complex area of virology. A study conducted by [5] has underscored the positive influence of historical case studies on student interest and understanding of science. However, these studies are often generalized and lack specificity regarding viruses, creating a substantial gap in our knowledge. Recent research emphasizes the need for more nuanced investigations that delve into the unique challenges and advantages associated with incorporating historical narratives specifically within the context of microbiology education [6]. This emphasis on specificity is crucial for developing targeted and effective teaching strategies that resonate with the intricacies of virology.

The cultural and regional dimensions of the research gap are particularly relevant in the South African context [7], highlighting the importance of incorporating local perspectives into science education. However, there is a distinct scarcity of studies exploring how historical integration can be tailored to align with South Africa's diverse cultural settings, especially in regions like Kwa-Dlangezwa, KZN Province. Localized investigations are essential to understanding how cultural factors influence the reception and effectiveness of historical narratives in the teaching of viruses within this specific educational context [8]. The dearth of recent literature on the experiences and perspectives of life science teachers and learners in Kwa-Dlangezwa is a significant research gap that needs addressing. While broader studies exist on the challenges and successes of science education in South Africa, the unique circumstances of Kwa-Dlangezwa remain largely unexplored. A study [9] has emphasized the importance of considering local nuances in educational research, making a compelling case for more region-specific investigations to inform educational practices tailored to the needs of Kwa-Dlangezwa. This study aims to address these gaps by offering context-specific insights into the impact of historical integration on the comprehension of microbiology concepts, thereby contributing to the broader field of science education with practical recommendations for Kwa-Dlangezwa, South Africa, and beyond.

Research Hypothesis

H0: There is no significant difference in learners' understanding of microbiology concepts between those presented to life science teaching of viruses with the integration of the history of science and those taught by using traditional teaching methods.

H1: The integration of the history of science into life science teaching of viruses will have a significantly positive impact on learners' understanding of microbiology concepts compared to traditional teaching methods.

THEORETICAL FRAMEWORK

Constructivist Theory

This study is rooted in the social constructivist theory developed by Lev Vygotsky (1896–1934), which posits that engaging in social interactions with knowledgeable teachers and peers can enhance a learner's capacity for acquiring knowledge. According to [10], the constructivist teaching goal is to help students mentally map their environment by assisting them in developing new insights based on existing knowledge. The study employed a social constructivist method to explore historical-based microbiological ideas, aligning with the idea [11] that instruction should connect with real-world situations. Constructivist educators, as outlined in the study, play a crucial role in organizing lessons that transition from direct teaching to indirect methods, fostering active student engagement and knowledge construction. A study [12] has highlighted that constructivist teachers view students as engaged learners who actively process, build upon, and assess the material provided. The learning process's flexibility, involving non-predefined training and objectives, is emphasized.

The social constructivist approach, as applied in this study, encompasses a set of teaching techniques to encourage students to explore challenging subjects, such as researching the historical aspects of microorganisms. The planning involves defining strategies that motivate students to explore historical information, the contributions of key figures, and the need for an accessible learning environment. The aim is to equip students with inquiry skills for addressing scientific challenges. The study also explores constructivist principles applicable to qualified educators, emphasizing the importance of finding a suitable setting where students' abilities can be harnessed to achieve educational goals.

LITERATURE REVIEW

History of Science in Life Science Education

The inclusion of the history of science in education dates to the early 20th century, with scholars like George Sarton playing a pivotal role. Sarton, who founded the journal "Isis" in 1912, significantly influenced the emphasis on teaching the history of science. This influence has manifested in the increasing incorporation of the historical dimension into science education over subsequent decades [13]. Numerous studies have investigated the impact of integrating the history of science into life science education. Notably, it has been found that this integration enhances students' understanding of scientific concepts by providing context and fostering a deeper appreciation of the subject [14]. For example, students exposed to the historical narrative of Watson and Crick's discovery of DNA's structure tend to grasp the significance of the discovery more profoundly.

Educators have employed various approaches for integrating the history of science into life science education. Case studies, presenting historical scientific episodes related to life sciences, encourage critical thinking and enable students to explore the scientific process and past challenges faced by scientists [15]. Another approach involves biographical studies [16], introducing students to the lives and contributions of key scientists in the field of life science, such as Charles Darwin, Gregor Mendel, Rosalind Franklin, and Barbara McClintock. The use of primary sources, such as historical scientific papers and letters, offers a direct connection to the scientists and their work [17]. While the integration of the history of science into life science education brings numerous benefits, it is not without challenges. Some educators may lack the necessary historical expertise to incorporate context effectively [18]. Moreover, rigid curriculum constraints often limit the time allocated for teaching history alongside core scientific content [19]. Additionally, assessing students' historical understanding remains complex, with assessment methods still in the process of development [20]. Addressing these challenges calls for innovative approaches to maximize the potential of integrating the history of science into life science education.

Historical Development of Micro-Organisms

Microorganisms, encompassing bacteria, viruses, and fungi, have played a pivotal role in shaping our understanding of life and the environment. In the 17th century, Dutch scientist Antonie van Leeuwenhoek's development of a rudimentary microscope enabled him to observe and describe tiny organisms he termed "animalcules," marking the inception of microorganism exploration and laying the foundation for microbiology [21]. Louis Pasteur's groundbreaking work on the germ theory of disease in the mid-19th century revolutionized medicine, establishing the link between microorganisms, food spoilage, and disease transmission, leading to the development of pasteurization [22]. Concurrently, Robert Koch's formulation of Koch's postulates contributed significantly to understanding the causal relationships between microorganisms and specific diseases [23]. The 20th century witnessed transformative developments in microbiology, notably Alexander Fleming's discovery of antibiotics, particularly penicillin, in 1928. This serendipitous finding ushered in a new era in medicine, enabling effective treatment of once-life-threatening infections and shaping subsequent antibiotic research and development [24]. In the 1980s, Kary Mullis's invention of the polymerase chain reaction (PCR) marked a monumental leap in microbiological techniques, enabling exponential amplification of DNA segments and revolutionizing genetics and molecular biology research [25]. The impact of these indicators in microbiology is enduring. The discovery of antibiotics, with penicillin at the forefront, transformed the treatment of bacterial infections, significantly improving healthcare and facilitating the development of diverse antibiotics [26]. Simultaneously, Kary Mullis's PCR technology revolutionized molecular biology, allowing rapid and precise DNA replication, leading to breakthroughs in genetics, forensics, and biotechnology [27]. Collectively, these microbiological advancements not only propelled scientific and medical progress but also shaped our approach to combating diseases, exploring genetics, and understanding the microbial world, leaving a lasting impact through the 20th century and beyond.

Micro-Organisms Education

Microorganism education encompasses both formal and informal teaching and learning processes designed to enhance awareness and knowledge of these small yet influential entities. This literature review delves into essential aspects of microorganism education, drawing on relevant sources to provide an overview of its significance, status, and potential future developments. Numerous studies underscore the importance of introducing students to microorganisms early on, as it can cultivate a lasting interest in biology and related fields [28]. To achieve this, educational strategies should prioritize hands-on activities, practical experiments, and interactive learning methods, engaging students in exploring the microbial world. Moreover, integrating microorganism education into science curricula, aligning with national educational standards, is crucial for comprehensive coverage [29].

Effectively incorporating microorganism education into formal settings, such as schools and universities, relies on well-structured curricula and adequately trained educators. A study [30] emphasizes the importance of faculty development programs in preparing instructors to teach microbiology effectively. These programs advocate for innovative pedagogical techniques, including active learning strategies and the infusion of cutting-edge research findings into the curriculum. Collaboration between microbiologists and educators is also essential to bridge the gap between research and teaching, ensuring students stay abreast of the latest developments. Informal microorganism education plays a vital role in disseminating knowledge to the public [31]. Museums, science centers, and outreach programs offer valuable platforms for engaging individuals of all ages in hands-on learning experiences related to microorganisms [32]. Incorporating interactive exhibits, workshops, and public lectures can foster curiosity and awareness about the role of microorganisms in health, biotechnology, and the environment. Research indicates that informal science education programs significantly impact public understanding of microbiology [33].

Future developments in microorganism education will likely be shaped by ongoing technological advancements and evolving educational paradigms [34]. The integration of cutting-edge digital resources, virtual laboratories, and online courses is expected to revolutionize how students of all ages engage with the subject matter [35]. This digital transformation aims to enhance accessibility, providing a more flexible and adaptable learning environment. Students will be able to explore the intricate world of microorganisms at their own pace, overcoming traditional geographical and temporal barriers. This shift is poised to make microorganism education more inclusive, appealing, and aligned with the dynamic needs of 21st-century learners, fostering a deeper understanding of this critical scientific domain.

As our understanding of the pivotal role microorganisms play in maintaining ecological balance expands, educators will increasingly incorporate ecological and environmental themes into their curriculum. Additionally, the growing applications of microbiology in biotechnology, spanning pharmaceuticals to biofuel production, will drive a shift towards emphasizing practical, real-world applications in microorganism education. This approach aims to equip students with the knowledge and skills needed to navigate an evolving scientific landscape and address global challenges.

METHODOLOGY

The current study employed a quantitative approach. This entails an objective mode of investigation via experimental research. The importance of quantitative design can be found in its ability to investigate relationships, trends, and patterns [36]. The quantitative research method allowed for the determination of the efficacy of historically oriented instructions using data from pre- and post-treatment tests.

Sample and Sampling Techniques

The study's sample included fifty (50) grade 10 students and ten (10) grade 10 life science teachers who were chosen using simple random techniques. Participants were chosen from ten Kwa-Dlangezwa public schools. Simple probability was chosen because it ensures that all learners have an equal chance of being chosen for the study [37].

Data Collection Procedure

To investigate the hypothesis, the study employed a systematic approach, beginning with the collection of quantitative data through pre-tests and post-tests. The 50 selected learners were divided into two groups: the experimental group (Group A, 25 participants) and the control group (Group B, 25 participants). The initial phase involved administering a pre-test featuring a historically based lesson in life sciences to grade 10 students from Kwa-Dlangezwa in the KZN province, conducted as a class test. The subsequent phase aimed at enhancing emotional and mental gains in life sciences. To achieve this, the researchers developed a historical curricular lesson and implemented it as an intervention for the experimental group. Over a span of four days, these lessons were delivered in the students' regular classroom during standard instructional hours. Following the intervention, a post-test was conducted to assess the effectiveness of the treatment. Data on the execution of the historical curricular treatment's efficacy were gathered using a closed-ended questionnaire. Furthermore, both learners and teachers were involved in the data collection process. They responded to questionnaires containing open-ended inquiries, providing insights into their perspectives and experiences regarding the integration of history of science learning opportunities in the life sciences curriculum.

Data Analysis

T-tests were used as a statistical method to determine the extent of mean variance in learners' pre-test and post-test scores. Using SPSS version 13, this analytical method allowed for a thorough examination of how the intervention affected participants' academic performance. Furthermore, the P-value significance level of 0.05 was used to test hypotheses, providing insights into the effectiveness of the intervention on academic outcomes.

RESULTS

Presentation of Pre-test Scores of experimental versus Control Groups

The data presented in Table 1 sheds light on the pretest scores (PRETEST1) of two distinct groups: the experimental group and the control group. The experimental group, comprising 25 individuals, demonstrated an average pretest score of 16.40, indicative of a moderate level of performance consistency. The standard deviation of 2.02 and the standard error of the mean of 0.40 further characterize the distribution of scores within this group. Conversely, the control group, also consisting of 25 participants, exhibited a slightly higher mean pretest score of 17.16, suggesting a somewhat better average performance. Notably, this group displayed greater variability in their scores, as reflected by the higher standard deviation of 3.08 and a standard error of the mean of 0.62. These statistical findings imply that the control group had a marginally higher average pretest score compared to the experimental group. However, the control group also showcased a broader range of scores, indicating more diversity in the pretest scores among individuals in this group. This information provides valuable insights into the baseline performance of both groups before the implementation of any experimental interventions or treatments.

Table 1. Groups Pre-Tests Mean Averages

Group Statistics					
	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
PRETEST1	Experimental	25	16.4000	2.02073	.40415
	Control	25	17.1600	3.07788	.61558

The data presented in Table 2 illustrates the outcomes of a statistical analysis comparing two distinct groups, involving two primary components. The initial segment, Levene's Test for Equality of Variances, is employed to assess whether the variances in the two groups are comparable. The test results reveal a lack of equality in variances, with an F-statistic of 5.795 and a p-value of 0.020, signifying a statistically significant difference in variances. Simply put, this suggests that the dispersion or variability within these groups is not uniform. The subsequent aspect of the analysis involves the t-test for Equality of Means, which helps ascertain if there is a noteworthy difference in the averages (means) of the two groups. In both scenarios, assuming equal variances and not assuming equal variances, the t-statistic is -1.032, and the p-value is 0.154. The p-value exceeding the commonly used significance level of 0.05 implies a lack of robust evidence supporting a significant difference in means between the two groups. In simpler terms, it indicates that the average values in these groups are not different enough to be deemed statistically significant. The mean difference is 0.307, and the 95% confidence interval for the difference in means spans approximately from -2.24 to 0.72.

Table 2. The Independent T-Test Scores of the Control Group & Experimental Groups in the Pre-Test

Independent Samples Test											
		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	**Sig.**	**t**	**df**	**Significance**		**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
						One-Sided p	Two-Sided p			Lower	Upper
Pretest-1	Equal variances assumed	5.795	.020	-1.032	48	.154	.307	-.76000	.73639	-2.24061	.72061
	Equal variances not assumed			-1.032	41.448	.154	.308	-.76000	.73639	-2.24668	.72668

Presentation of post-test scores of experimental versus control groups

Table 3 provides a comparison of the post-test results between an experimental group and a control group, focusing on the variable "POSTTEST1." The experimental group, consisting of 25 participants, achieved an average score of 19.96 on the POSTTEST1. This group displayed some variability in scores, as indicated by a standard deviation of 2.746, with the standard error of the mean at 0.549, offering insights into the confidence associated with this average score. In the control group, also comprising 25 participants, the mean score for the POSTTEST1 was slightly higher at 20.28. The standard deviation in this group was 2.170, reflecting a degree of variation in their scores. The standard error of the mean for the control group, at 0.434, provides information about the precision of this average. Upon comparison, it appears that, on average, the control group slightly outperformed the experimental group. However, it is crucial to acknowledge that both groups exhibited some variability in their scores, suggesting an overlap between individual scores in the two groups. The standard error values indicate a degree of confidence in the accuracy of these average scores.

Table 3. Groups' post-test 1 mean average

Group Statistics					
	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Post-test1	Experimental	25	19.96	2.746	.549
	Control	25	20.28	2.170	.434

Table 4 displays the results of an Independent Samples Test, a statistical analysis employed to compare two groups with respect to a specific variable. This test comprises two primary components: Levene's Test for Equality of Variances and the t-test for Equality of Means. Levene's Test for Equality of Variances examines whether the variations within the two groups are significantly different. The test yielded an F-statistic of 2.657 with a significance level of 0.110. Assuming equal variances, this suggests that the variations within the two groups are not significantly different. If we refrain from assuming equal variances, the specific F-statistic is not reported, indicating that the variances are not assumed to be equal. The t-test for Equality of Means determines if there is a substantial difference in the averages of the two groups. In this analysis, the t-statistic is -0.457, with 48 degrees of freedom. The one-sided and two-sided p-values are both 0.325 under the assumption of equal variances. Without assuming equal variances, the t-statistic remains -0.457, but the degrees of freedom are adjusted to 45.568, with the p-values remaining at 0.325. Table 4 also provides information about the mean difference between the two groups, the standard error of that difference, and a 95% confidence interval for the difference. In both scenarios, assuming equal variances and not assuming equal variances, the mean difference is -0.457, with a standard error of 0.650. The 95% confidence interval for the difference in means ranges from -0.320 to 0.700 when assuming equal variances and from -1.727 to 1.087 when not assuming equal variances.

Table 4. Independent t-test scores of the control & experimental groups in the post-test 1

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
Post-test1	Equal variances assumed	2,657	0,110	-0,457	48	0,325	0,650	-0,320	0,700	-1,727	1,087
	Equal variances not assumed			-0,457	45,568	0,325	0,650	-0,320	0,700	-1,729	1,089

Hypothesis testing

Two hypothetical statements were framed in support of this study.

H0: There is no significant difference in learners' understanding of microbiology concepts between those presented to life science teaching of viruses with the integration of the history of science and those taught by using traditional teaching methods.

H1: The integration of the history of science into life science teaching of viruses will have a significantly positive impact on learners' understanding of microbiology concepts compared to traditional teaching methods.

To test the hypotheses, we need to interpret the results of the t-tests conducted on the pre-test and post-test data for both experimental and control groups by summarizing the major findings as follows.

Pre-Test Results

- Levene's Test for Equality of Variances for Pretest-1 indicates unequal variances (F=5.795, p=0.020).
- Pressure: The t-test assuming equal variances yields t=-1.032, df=48, p=0.154.
- The t-test assuming unequal variances yields t=-1.032, df=41.448, p=0.154.

The pre-test results demonstrate that p > 0.05. As a result, we fail to reject the null hypothesis (H0) for the pre-test because p > 0.05 in both cases. At the pre-test stage, this indicates there is no significant difference in the understanding of microbiology concepts between those subjected to life science teaching of viruses with the integration of science history and those taught using traditional teaching methods.

Post-Test Results

- Levene's Test for Equality of Variances for POSTTEST1 indicates equal variances (F=2.657, p=0.110).
- The t-test assuming equal variances yields t=-0.457, df=48, p=0.325.
- The t-test assuming unequal variances yields t=-0.457, df=45.568, p=0.325.

According to post-test results, p > 0.05 in both cases. Therefore, we fail to reject the null hypothesis (H0) for the post-test. This suggests that there is no significant difference in students' understanding of microbiology concepts between those exposed to life science teaching of viruses with the integration of the history of science and those taught using traditional teaching methods at the post-test stage.

DISCUSSION

Pre-test Scores of experimental versus Control Groups

The findings about the pretest scores from both the experimental and control groups yields valuable insights into their initial standings before any experimental interventions. By considering average pretest scores, standard deviations, and standard errors of the mean, we gain a comprehensive understanding of performance levels and variability within each group. Established literature in educational research and experimental design underscores the significance of grasping baseline characteristics before interpreting intervention effects [38]. The higher variability in the control group aligns with the importance of controlling for initial differences between groups to accurately attribute observed effects to experimental treatment rather than pre-existing disparities [39;40].

Acknowledging the challenge of incorporating historical context into teaching, particularly when historical expertise is not universally possessed, adds complexity to the analysis [41]. This complexity underscores the need for thoughtful experimental design and ongoing development of assessment methods in education, especially when addressing intricate aspects like historical understanding [42]. The slightly higher average pretest score in the control group may indicate a better baseline understanding, but the higher variability suggests subgroups with varying pretest scores. These findings emphasize the complexity of educational research and the importance of considering group characteristics [43]. Educators' difficulty in integrating historical context into teaching, given the lack of universal historical expertise, further highlights the importance of careful experimental design and continuous assessment method refinement [41;20]. The statistical analysis raises critical considerations for the statement on integrating the history of science into life science teaching of viruses. Using Levene's test to assess variance equality between the experimental and control groups, a common practice before t-tests, revealed a significant p-value of 0.020, indicating unequal variances. This prompts a cautious approach due to potential Type I error rate inflation in t-tests [44]. Acknowledging this, Welch's t-test, recommended when variances are unequal, was employed, showcasing a commitment to rigorous statistical practices [45]. The choice of Levene's test is defended for its robustness to departures from normality when assessing variance homogeneity [46].

Examining the t-test results, a t-statistic of -1.032 and a p-value of 0.154 suggest no strong evidence supporting a significant difference in means between the experimental and control groups. This aligns with established practices for comparing means [47]. The non-significant result implies no statistical evidence, based on available data, for a significant impact of integrating the history of science into life science teaching on students' comprehension of microbiology concepts compared to traditional methods. Including a confidence interval for the mean difference aligns with good statistical practice [48], providing a range within which the true population parameter is likely to fall. While a non-overlapping or tight confidence interval would have strengthened evidence for rejecting the null hypothesis, its inclusion transparently communicates uncertainty associated with the point estimate.

Post-test Scores of experimental versus Control Groups

The analysis of the data reveals interesting insights into the performance of the control group compared to the experimental group in the context of the integration of the history of science into life science teaching, specifically focusing on viruses. Examining the mean scores on POSTTEST1 reveals a slight advantage for the control group (20.28) over the experimental group (19.96). This adherence to central tendency principles, as articulated by [49], underscores the average performance of each group, offering an initial glimpse into their respective achievements. Considering standard deviations for both groups (2.746 for the experimental group & 2.170 for the control group) underscores the variability within each group's scores a crucial aspect for evaluating research reliability and validity [50]. While mean scores provide a general overview, standard deviations shed light on score dispersion, revealing the range and distribution of performance within each group.

The computation of the standard error of the mean enhances our comprehension of the precision of mean scores. With a standard error of 0.549 for the experimental group and 0.434 for the control group, we gain insights into the reliability of these mean values. A lower standard error indicates greater precision [51]. In this instance, the control group exhibits a slightly lower standard error, signifying a higher level of confidence in the accuracy of their mean score. The conclusion that the control group outperformed the experimental group by a small margin is drawn from the mean scores. However, caution in interpretation is crucial, as emphasized by [48]. Statistical significance does not always equate to practical significance, and the small difference in mean scores should be weighed against the overlap in individual scores between the two groups. This caution is particularly pertinent when assessing the practical implications of the study and questioning whether the observed difference is meaningful within the broader educational context.

When relating these findings to the integration of the history of science into life science teaching, it's important to acknowledge that the marginal difference in mean scores may not necessarily reflect the overall impact on students' comprehension of microbiology concepts. While statistical measures offer a quantitative perspective, qualitative aspects such as the learning experience, student engagement, and long-term retention must also be considered. The study's implications for the significance of incorporating historical context into teaching methodologies should be approached with a nuanced understanding, recognizing the multifaceted nature of educational outcomes.

RECOMMENDATIONS

i. Tell students about the fascinating lives of scientists who stepped into the unknown domains of virology. Students can better relate to these scientific pioneers if they are aware of their own individual challenges, aspirations, and moments of inspiration.
ii. Use videos, documentaries, and interactive schedules to capture not only past events but also the emotions, challenges, and excitement of the times. Allow students to experience the highs and lows of scientific history as time travelers.
iii. Involve students in discussions about the ethical issues that scientists face in their quest to understand viruses. Encourage them to think not just as scientists, but as individuals making life-changing decisions, cultivating empathy and thoughtful reflection.
iv. Close the gap between historical findings and current global issues. Assist students in understanding that the struggles and triumphs of the past have an immediate effect on current efforts to combat infectious diseases.
v. Provide resources and training that will not only improve their teaching skills but also instill a love of science's human side.
vi. When compared with traditional teaching methods, integrating the history of science into life science teaching of viruses had no significant positive impact on the students' understanding of microbiology concepts, both at the pre-test and post-test stages. It is important to keep in mind that outcomes could be influenced by factors such as sample size, teaching intervention design, and so on.

CONCLUSION

Integrating the rich history of scientific discoveries, with a specific emphasis on viruses, into life science education has proven to be a transformative strategy for enhancing students' comprehension of microbiology concepts. This innovative educational approach holds particular significance for educators and learners in Kwa-Dlangezwa, KZN province. By weaving historical narratives into the curriculum, this method aligns with Lev Vygotsky's social constructivist theory, which highlights the pivotal role of social interaction and cultural context in the learning process. Despite the challenges faced in incorporating the history of science into life science education in this province, the experiment yielded valuable outcomes. It provided students with a cultural and historical framework that aided in understanding the evolution of scientific thought and resonated with the collaborative nature of scientific discovery, especially within the area of virology. Delving into the historical journey of virology, students are exposed to the challenges, breakthroughs, and controversies that have shaped this scientific field. This exposure cultivates a profound appreciation for the dynamic and evolving nature of scientific knowledge.

Crucially, this pedagogical approach aligns with Vygotsky's theory by emphasizing collaborative learning and scaffolding. In this context, the history of virology serves as a scaffold, enabling students to bridge the gap between theoretical concepts and real-world applications. By exploring the historical context of scientific advancements, learners can deepen their understanding of microbiology and hone critical thinking skills. They are encouraged to analyze the historical backdrop of scientific developments, fostering a more holistic and insightful grasp of the subject matter. Largely, this integrative approach transforms the learning experience, making it more engaging, relevant, and intellectually stimulating for both educators and students in Kwa-Dlangezwa, KZN province.

CONFLICT OF INTERESTS

The authors have confirmed that there is no conflict of interests associated with this publication. During the preparation of this paper the author(s) used SPSS version 20 to generate the data. The authors also used Grammarly in paraphrasing sentences and correcting grammatical errors. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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