**Edelweiss Applied Science and Technology**
*ISSN: 2576-8484*
*Vol. 8, No. 5, 74-87*
*2024*
*Publisher: Learning Gate*
*DOI: 10.55214/25768484.v8i5.1632*


# Transforming research and pedagogy in higher education through scientific inquiry steps

Kofi Nkonkonya Mpuangnan[1*], Buthelezi Penelope Zamashenge Gugulethu[1]

[1]University of Zululand, South Africa; Nkonkonya@gmail.com (K.N.M.); ButheleziP@unizulu.ac.za (B.P.Z.G.).

**Abstract:** This research aims to investigate how to transform study and pedagogy in higher education through scientific inquiry steps. Scientific research serves as the foundation for human development. It drives humanity forward into discovery and innovation. The purpose of this study is to explore how teachers and researchers apply scientific inquiry steps to improve research and pedagogy in higher education in South Africa. Constructivist theory serves as the foundation for the study. Therefore, we employed a qualitative method and phenomenology design to explore the lived experiences of participants. The participants included ten experienced researchers doubling as teachers in the field of science education. We selected these participants from ten public universities in South Africa using a purposive sampling technique. The main instrument for data collection was a semi-structured interview schedule, which covered scientific inquiry steps. Recordings were made of the data with the permission of the participants, later transcribed into a notebook, and analyzed thematically. The findings indicated that teachers and researchers were aware of the scientific inquiry steps. Most of them benefited from scientific inquiry, which included constantly refining methods, embracing diverse perspectives, and revisiting hypotheses and experiments. Also, scientific inquiry steps enhanced the effectiveness of their teaching practices and provided them with a reliable scope for making informed decisions in the ever-evolving educational environment. This study has practical implications, including creating opportunities in higher education for both prospective teachers and emerging researchers to acquire a rigorous education in the scientific inquiry steps. This approach forms the bedrock for acquiring knowledge and promoting best practices in education.
***Keywords:*** *Constructivist theory, Effective teaching, Higher education, Research, Pedagogy, Scientific process.*

## 1. Introduction

The role of scientific research in higher education is crucial for enhancing teachers' pedagogical content knowledge (PCK). The PCK demands that teachers possess an in-depth understanding of their subject matter. Mastery of content is vital for effective teaching, curriculum development, engaging students, and enhancing the overall educational experience. The PCK acquisition process entails a series of training sessions and selfless learning. A notable learning process is the scientific inquiry step [1]. This means learning entails a specific academic effort characterized by inquiry and concentration. The transition into science necessitates a definite or deliberate process of going from the dark into the light [2]. Scientific investigation therefore occurs in stages [3] to help researchers as well as teachers learn through investigation. The process begins with the formulation of questions and progresses through the stages of making assumptions, learning, conducting tests, processing data, and drawing conclusions [4]. Every step shows the path that must be followed, developing the understanding of the subject matter and resulting in new ideas and novelties. Trew, et al. [5] proclaim that having the scientific inquiry steps implemented in teaching and learning enhances learning. Thus, it can benefit higher


**History:** Received: 14 March 2024; Revised: 31 July 2024; Accepted: 20 August 2024; Published: 11 September 2024
* Correspondence: Nkonkonya@gmail.com

education students by helping them become scientifically literate people who will be able to assess scientific knowledge and make correct decisions in the contemporary world.

Rönnebeck, et al. [6] noted that the scientific journey is not limited to a single discipline but crosses the boundaries of various fields, integrating diverse methodologies, paradigms, and approaches. Buthelezi and Mpuangnan [7] argue that each discipline, whether it's the exactitude of laboratory sciences or the investigations in life, natural, and physical sciences, as well as teaching pedagogy, follows its distinctive path of inquiry. Despite these diversities, all fields share a commitment to empirical observation, reasoning, and systematic exploration, guiding researchers through the process of discovery. However, researchers often face unforeseen challenges, unanswered questions, and unexpected results [8]. Yet, it is their resilience, adaptability, and determination that turn setbacks into stepping stones, driving the relentless pursuit of knowledge forward. This ongoing quest to unravel the mysteries of existence reflects the researchers' inherent drive to understand the world. Therefore, it is crucial to explore the sequential stages of this continuous process.

Understanding the scientific process is crucial because it provides a structured framework for comprehending the world, fostering progress, and driving innovation. This process is particularly critical for higher education teachers and researchers in South Africa. This is because the Department of Higher Education is committed to improving the country's teaching and research quality over the years. In 2018, for instance, South Africa introduced the University Capacity Development Programme to boost staff development, improve curriculums, and support student success in higher education [9]. Despite this initiative, Monnapula-Mapesela [10] highlighted the need to revisit the plethora of research models and innovation programs in South Africa's higher education system because of their inaccessibility. Similarly, other research studies such as Mtshali and Sooryamoorthy [11] and Taylor [12] emphasized the growing need for more targeted interventions to enhance quality teaching and research in South Africa. These lingering issues prompt crucial questions: How do new technologies transform the conventional steps of scientific investigation? What are the adaptive strategies employed by researchers as they progress through the stages of scientific inquiry? How does the cyclical nature of scientific inquiry fuel continuous refinement and revaluation? How relevant are the scientific inquiry steps for teachers, especially when selecting teaching methods? Addressing these questions is important because it involves revisiting the steps of scientific inquiry. Sommer, et al. [13] established that the cyclical nature of scientific inquiry, where hypotheses are continually formulated, tested, and analyzed, has not been fully examined for its role in ongoing refinement and re-evaluation. Understanding how scientists engage in these processes can inform the driving forces behind scientific progress.

## 2. Literature Review

### *2.1. Scientific Inquiry Steps*

Scientific inquiry is the foundation of teaching and research. It serves as a process by which knowledge is acquired through investigating a natural phenomenon, leading to theory development. According to Sommer, et al. [13], scientific inquiry steps mean a step-by-step approach to knowing. Sommer, et al. [13] and Rönnebeck, et al. [6] further indicate that the step-by-step process of knowing includes observation, hypothesis formulation, experimentation, data collection and analysis, and communication of findings. This structured approach is significant to both teachers and researchers as they continue to develop their knowledge and skills in scientific investigations. Similarly, Rees, et al. [3] expanded on these scientific steps by creating a framework tailored for pre-service teachers. The framework features stages such as engagement, exploration, explanation, elaboration, and evaluation. This approach highlights the value of reflective practice and effective learning, allowing pre-service teachers to hone their inquiry skills through practical experience and ongoing feedback.

Moreover, Germann [14] introduces the "Inquiry I" model, which emphasizes starting with an initial question, conducting investigations, interpreting the results, and repeating the process. This model showcases the evolving nature of scientific inquiry, where each study leads to new questions and further exploration. Tang, et al. [15] highlight the dynamic and iterative aspects of scientific inquiry, contrasting it with the traditional, more linear scientific method. They stress the need for flexibility and adaptability in the inquiry process, which includes questioning, investigating, analyzing, reflecting, and revising based on new findings. All the scientific inquiry steps presented here provide teachers and researchers with a comprehensive understanding of scientific investigation and learning.

### *2.2. Adaptive Strategies Employed by Researchers in Scientific Inquiry*

Adaptive strategies are pivotal in scientific inquiry, driving researchers towards groundbreaking discoveries and novel insights across various fields. One such strategy involves leveraging technological advancements [16]. Consider astronomy's use of cutting-edge telescopes like the Hubble Space Telescope, which revolutionized our view of the universe. By adapting to advanced observational tools [17], astronomers unveiled distant galaxies and observed celestial phenomena with unprecedented precision, unlocking new frontiers in space exploration. Interdisciplinary collaboration is crucial in scientific inquiry [18]. In disciplines like bioinformatics, merging expertise from biology, computer science, and statistics enables researchers to navigate vast biological datasets. This adaptive fusion of knowledge and methodologies leads to breakthroughs in genomics, personalized medicine, and the comprehension of intricate biological systems. Adaptive experimentation techniques are also fundamental, especially in pharmaceutical research [19]. Adaptive clinical trials, for instance, allow researchers to adjust trial parameters based on interim results. This adaptability speeds up the discovery of effective treatments and unexpected benefits or risks of drugs, potentially revolutionizing medical progress and patient care.

Other adaptive strategies employed by researchers in scientific inquiry include dynamic modelling and simulation methods, which therefore fall particularly in areas such as climatology or climate science [20]. This gives scientists an opportunity to use adaptive models that assimilate new data in sequences and fine-tune the forecast, besides enriching their comprehension of complicated climate systems [21]. Public policy practitioners utilise this adaptive modelling to anticipate the changes in the environment and determine the most appropriate set of policies and strategies to address climate change influences [22]. Adaptive hypotheses and their subsequent testing are critical in evolutionary biology, fostering scientific research Jockusch and Ober [23]. Hypotheses undergo revisions based on new evidence, fossils, genetics, and the earth's ecosystems. It constantly results in new species being found, helps to explain relationships between the species, and strengthens overall biology knowledge of species distribution within the world [24]. Innovation stands as a critical factor in scientific excellence, including the flexible approaches to solving problems. Thus, relying upon technological advancement, integration of wider cross-referencing, operation of volatile, highly adjustable experiments, and generating hypotheses under ever-changing circumstances, scholars dwell in ever-developing lines of research and enhance the advancements made in science fields.

Examining the literature identified in the preceding paragraphs has shown that there are difficulties in comprehending adaptiveness within the scientific process. High technology like advanced telescopes has greatly enhanced astronomy, but it requires the study of how most fields apply these technologies. In further studies, the effects of interdisciplinary collaboration are yet to be understood, and more research is required. For instance, in pharmaceutical research, there is a hint of adaptivity in experimentation techniques, but integrating their efficiency and drawbacks needs further discussion. Likewise, time-varying analysis and its application as part of dynamic modelling in climate science is time-varying and must evolve, which is better explored here. Finally, the possibilities of hypothesis generation establish this, common in evolutionary biology, as adaptable, but its full potential is still unknown. The former would strengthen the knowledge base needed for accounting adaptive strategies, while the latter would allow for better scientific advancement across disciplines.

### *2.3. Significance of the Cyclical Nature of Scientific Inquiry Steps to Continuous Refinement and Revaluation*

The scientific method, as the cycle and steps of scientific endeavours, represents the progression of remarkable discoveries throughout the biological and other sciences. It calls for a delicate start, in which one first observes and investigates everything associated with a given topic before making the next significant step [6]. A classic example is the story of Alexander Fleming, who by accident discovered that mold could prevent bacterial growth. This led to a sequence of more elaborate experiments as well as the development of hypothesized and tested hypotheses, which resulted in the discovery of the antibiotic penicillin. The cyclical process of hypothesis formulation, experimentation, analysis of results, drawing conclusions, and the formulation of new hypotheses is important in education in the following ways: It prompts cognitive engagement, enhances the learning process, helps obtain a better understanding of the scientific approach, enables one to identify the links between fields, and prepares individuals for the practical application of the received knowledge [25]. The observation, data synthesis, and hypothesis generation that form this cyclic process from which the ground-level bending is formed provide the foundation for unpredictable discoveries and substantial advances [26].

Another important component of this scientific cycle is the formation and elaboration of hypotheses Pro, Sahu [27]. This process was adopted by Watson and Crick [28] in formulating hypotheses and experimenting, leading to the discovery of the structure of the deoxyribonucleic acid (DNA). Watson and Crick significantly advanced the understanding of genetics by formulating hypotheses, designing tests, and making revisions based on new discoveries. In addition, the application of data analysis and the subsequent interpretation of the analysed data dovetail with each other to form a cyclic loop of continuous inquiry in science [29]. A telescope can facilitate observation in astronomy. This entails a cyclic tracking and enhancement step that may lead to the discovery of a new phenomenon or a paradigm that confirms a hypothesis. Such a relentless practice of analysis, reviewing theories, and refining interpretations often leads to paradigm shifts and profound learning [30].

In addition, the practice of peer review and the concern for colleagues' work creates cyclical engagement in science [31]. Scholars and researchers do ask their papers to go up for peer review, and this is where the process of discussion modification and enhancement is done. Scientists combine their efforts on various fronts, resulting in a variety of styles that enhance the density and reliability of their inquiries [32]. Such a cycle of review and collaboration enhances the usability and reliability of discoveries made within the scientific community. Finally, translated and disseminated results conclude a cyclical loop in the process of scientific investigation [33]. Researched facts can be a starting point for innovative technologies, products, medical treatments, or changes in policy. It is a cycle of discovering something and then applying it to create something new, with the feedback forming the basis of another question; this stimulates development and growth in societies [34].

The cyclic nature of scientific investigation is clearly indicated by the literature as being essential in development of the breakthrough ideas across disciplines. However, there are some limitations, such as issues with collaboration across disciplines, the representation of minorities in editorial boards, the elegance of methods used in data analysis, and communication approaches. These are issues that need to be filled for an all-encompassing science to be achieved; therefore, there is a need for more research to be done and the issues under review to be fine-tuned.

### *2.4. Relevance of Scientific Inquiry Steps for Teachers*

For teachers, the idea connected with the steps of the scientific inquiry is rather important, especially when choosing the methods of their work. Schwartz and Crawford [35] further explain that through research, teachers get a framework that helps them approach issues that relate to the process of teaching and learning and dissect them in a systematic manner. So following this systematic account would enable the teachers to assess the impact of teaching approaches [36]. Learning about the best practices enables teachers to make improved decisions as to the best mechanism to be used in the teaching-learning process to meet the intended goals and objectives. Observation is another critical feature of scientific research endeavours and scientific research in general [37]. In learning environment analysis, it is possible to use observation to track students' behaviour. This may differ from teacher to teacher due to different learning environments and the teachers' evaluation approach. The


*DOI: 10.55214/25768484.v8i5.1632*

observation facilitates evidence-based decision-making at the classroom level [38], thus providing teachers with appropriate strategies for managing Learning Support Teams (LSTs) [39].

Furthermore, scientific inquiry entails and enables teachers to conduct research on the best practices and institutionalize ways of evaluating different teaching practices within the classroom and their effectiveness on student achievement [40]. As a result, teachers can evaluate the potential benefits of the given instructional strategies [36] and determine which of them provides the most beneficial outcomes for learners by conducting controlled research and gathering data on learners' performance. This facilitates the decision-making process by providing teachers with more time for analyzing and making improvements to the lessons taught in their classrooms.

Additionally, scientific investigation draws attention to the importance of collecting and using data [41]. The learning outcomes, rate of reinforcement, feedback from a student, and other results show the efficiency of teachers' work. Processing this data can help teachers learn patterns or trends, possible issues arising in their classes, and ways to improve them [42]. With such insights, the teachers can be evident in ways that they transform their methodologies. This suggests that data collection and interpretation are crucial stages of introducing any scientific discovery. Therefore, we can detect significant gaps in understanding the long-term effects of specific teaching approaches on students' academic achievements [43, 44]. Filling these research gaps is crucial for teachers to be equipped with knowledge in making proper decisions in strategies for their instructions and to check whether the instructional techniques they use favour the learning of the diverse students they encounter in their classroom.

### *2.5. The impact of technologies on transforming conventional scientific investigation processes*

Today's scientific research environment has undergone a significant transformation due to advanced technologies and unorthodox approaches [45]. Of particular interest is the way in which the following innovations are transforming scientific investigation, experimentation, and comprehension of different processes: This has an impact on everything from the mode of hypothesis formulation to the data analysis process. The Clustered Regularly Interspaced Short Palindromic Repeats and CRISPR-associated protein 9 (CRISPR-CAS9), for instance, have made huge changes to the way experiments are done [46]. It is a revolutionary technique that has enabled the fine, quick, and accurate manipulation of an organism's genome, bringing new possibilities to biological science. Previously, researchers have thought about the accomplishments of such technology and how it can help them learn about gene functions, disease onset, and other related issues, including possible treatments. However, these new strategies have also sparked a shift in the approach to developing and evaluating hypotheses. The former is quantum computing, which has its origins in quantum mechanics and is another ideal example [47]. Unlike classical computers which use traditional bits, quantum computers, utilise quantum bits or their qubits, which make computations at such a rapid rate that existing paradigms are altered. Science and technology experts now have no option but to reconsider their conceptualization of computational capacities in light of this disruptive innovation.

Furthermore, Maxwell [48] observed that emerging technologies have transformed the management of data within an organization. For example, the Large Hadron Collider (LHC) in astrophysics is a circular machinery that reconstructs petabytes of data resulting from particle collisions; it calls for new ways to process information. Machine learning techniques, for example, allow scientists to search through a large amount of data, analyze it search for particle patterns, and uncover new physics. They have similarly influenced communication and sharing of the findings within and between institutions or departments. Other crowdsourcing tools, such as Foldit, involve ordinary citizens in solving existing problems in protein folding by taking advantage of a huge pool of human brains in the whole world. This approach expedites the interpretation of protein structures and facilitates both enthusiasm and new discoveries in drug design.

Emerging technologies also lead to cross-disciplinary research that goes beyond the usual boundaries [49]. A good example of this is bioinformatics, which merges biology, statistics, and computer science to analyze biological data, reveal complicated biological processes, and speed up discoveries in genomics, personalized medicine, and evolutionary biology.

From the above paragraphs, it is clear that emergent technologies and unconventional methods have transformed scientific research and exposed multiple areas of research gaps. For instance, CRISPR-Cas9 has fundamentally transformed genetic studies, but long-term implications as well as ethical concerns are still under examination. Also, the rise of quantum computing contradicts traditional computational frameworks, thereby demanding further study into computation capacities. Data analysis advancements, as seen in the use of large Hadron colliders require new approaches such as machine learning, but scalability issues and interpretability remain challenges. Collaborative platforms like Foldit have increased the research pace but also come with concerns about data security and quality control. Bioinformatics is an example of interdisciplinary collaborations that speed discoveries; however, effectively incorporating different fields is still difficult. It is critical to fill these gaps so that emergent technologies can maximize their benefits while mitigating associated risks.

## 3. Theoretical Framework

*3.1. Constructivist's Theory*

This study is based on a theory called constructivism. This theory emphasizes that people must build knowledge through their experiences and thinking [50]. Researchers can learn how to apply the steps of scientific inquiry using constructivism. This is shaped by what they already know and what they have experienced. Constructivist theory further demonstrates how important it is for researchers to use what they already know in each step of the scientific process [51]. This alters the learning process for researchers suggesting that they gain knowledge by comprehending the scientific realm. Therefore, it is critical to actively engage and build knowledge. This can be done by learning about the world through experience and thinking. We used constructivist theory in this study to facilitate the investigation. Additionally, the theory assisted in examining significant issues in scientific inquiry and infused meaning into the learning process. Therefore, it can be recommended for other researchers and teachers during their scientific inquiry journey.

## 4. Methodology

*4.1. Research Design*

This study adopted a qualitative approach to address the research questions. The decision is based on the detailed perspectives of the field participants. According to Gay, et al. [52], qualitative research is particularly suitable for answering complex questions in greater depth (p. 3). Additionally, a phenomenology design was used to explore the lived experiences of teachers, who also serve as researchers in higher education. The investigation focused on their perspectives regarding the steps of scientific inquiry. It assisted in presenting a more complete, colourful image of the phenomena being investigated.

*4.2. Research Population*

The study looked specifically at researchers in the field of science education. Therefore, we selected a sample of 20 experienced science education researchers from 10 public universities in South Africa using a purposeful sampling technique. In order to collect unbiased and comprehensive data, the head of the science education department at each university was intentionally selected for the study. This technique involves selecting participants based on their knowledge and expertise in the study field [52]. Using heads of departments from different universities introduced more varied opinions and experiences to this study.

*4.3. Instrument*

This study collected data through interviews, guided by a semi-structured interview schedule. These schedules followed topics such as the adaptivity within scientific inquiry to inform research practice, the strategies for scientific inquiry, the cyclical nature of the inquiry process, and the transformation of traditional scientific inquiry and discoveries by emerging scientific technologies.

*4.4. Validity and Reliability of Instrument*

We consulted three experts in science education to validate the interview schedule. They were consulted for content validity and grammatical accuracy. The experts' feedback ultimately led to the revision of the instrument. This step was useful in improving the quality of the instrument for collecting appropriate data.

*4.5. Data Analysis*

The researchers stated that data collection started with the approval of the universities involved. The researchers subsequently approached the participants to obtain their informed consent and to schedule a convenient time for time for an interview. The interviews lasted 45 minutes with each participant. The consent of the participants was sought for tape recording, which was later transcribed into a notebook for thematic analysis. Unique codes were used to label each participant to streamline the analysis and aid the interpretation and organization of the recurring themes identified from the data. Each of the ten codes, R1-R10, was assigned to a researcher based on their involvement in the study.

## 5. Findings

The findings from the study data were categorized into three titles resulting from the emerging themes. The themes include the adaptive strategies employed by researchers in the scientific inquiry process, the significance of the cyclical nature of scientific inquiry steps to continuous refinement and revaluation, the relevance of scientific inquiry steps for teachers, and the role of technologies in redefining traditional scientific inquiry steps. The following are the details of the findings:

*5.1. The Adaptive Strategies Employed by Researchers in the Scientific Inquiry Process*

Here, participants described the adjustments scientists make as they move through the stages of scientific inquiry on their way to fruitful discoveries. The participants had to say:

*$R_1$: To survive in the research cycle, I constantly solicited new ideas. I do this by refining my methodologies, considering other viewpoints, exploring new insights, and devising new approaches to solving problems.*

*$R_2$: There are ways to adapt and adjust to new situations in this field. Some of the adaptive strategies include testing new hypotheses, redesigning experiments, or using new technologies or analytical tools to make new discoveries.*

*$R_3$: As a researcher, I collaborate with other researchers to gain knowledge and experience. I do this by joining forces with other disciplines to solve complex problems and discover new avenues for breakthroughs.*

*$R_4$: I perform a lot of experiments to solve problems in my field. Each experiment presents a different challenge, but I remain resilient and revise my methodologies in response to unexpected results or issues that arise during experiments.*

*$R_5$: Discussion with other experts on one of the strategies that work for me in problem-solving. I shared my research problems with my colleagues, and after a lengthy discussion, I got a solution.*

*$R_6$: In my field, resources are critical. For every research problem, I gather the required materials for the experiment before starting it. For this reason, most of my research work is funded by grants, which provide money for the purchase of the materials.*

*$R_7$: Technology has been very helpful to me in my research. This is the fastest way I get my work done.*

*$R_8$: For me to start any research work, I ask myself so many questions relating to how well the project could be executed. I also consult past experiments and investigate emerging evidence or paradigm shifts, to get new perspectives.*

*$R_9$: I begin my research with a problem, then explore literature to justify it. Then, after, I frame the hypothesis and collect data to test it and draw conclusions.*

*$R_{10}$: You know that scientists use scientific methods to solve problems. Apart from such steps, as we all know, I also analyse failed experiments, making sure that they work for my subsequent studies."*

The responses presented above show that researchers in higher education in South Africa are keen to follow a laid-down approach to problem-solving. Many of them progress through the stages of scientific inquiry by constantly refining methods, embracing diverse perspectives, revisiting hypotheses, and conducting experiments to test the proposed hypotheses. Also, some researchers prefer to integrate new technologies, fostering collaboration across disciplines to enrich their research work. Good communication, good resource management, and the ability to change direction quickly are also important. Scientists must innovate by exploring new directions, taking chances, and acting in the best way they can at every step. All of these adaptive strategies serve as a scaffold for moving scientists' activities forward to new perspectives.

*5.2. Significance of the Cyclical Nature of Scientific Inquiry Steps to Continuous Refinement and Revaluation*

This section of the study presents data about the influence of the cyclical nature of scientific steps on continuous refinement, re-evaluation, and discoveries. The participant's responses are as follows:

*$R_1$: "The cyclical approach seems to follow nature. Nature has many seasons, which we must observe as they change constantly. Each of these cycles provides learning opportunities for adjustments."*

*$R_2$: " Scientific steps are helpful. Each of the steps, like observation, hypothesis, and experimentation, enlightens us and provides new knowledge."*

*$R_3$: "The cycle nature of scientific steps provides new ideas amidst challenging circumstances. This is critical for me as a researcher."*

*$R_4$: "In science, I enjoy every step involved. Each step adds new knowledge and enriches my understanding."*

*$R_5$: "Although there are complexities in scientific knowledge, each step produces new knowledge. This is what I get from it."*

*$R_6$: "I do know that scientific processes are cyclical and are useful for refining and understanding new concepts."*

*$R_7$: "The cyclical process of science constantly upgrades my understanding of the things around us."*

*$R_8$: "Exploring the steps involved in scientific inquiry is critical for unveiling issues and ideas scientifically. It must be encouraged in teaching and learning processes.*

*$R_9$: "In the scientific field, we try to understand human behaviour. Exploring the cyclical steps defined in science can make this possible."*

*$R_{10}$: "The process is useful for guiding us to solve everyday problems, especially in research.*

The above participants have acknowledged the significance of the cyclical nature of scientific inquiry steps as a critical concept in facilitating learning, discovery, and knowledge acquisition. Its role as perpetual evolution was emphasized for better understanding. It further makes new ideas better and everyday activities more reliable. This demonstrates the ability to adapt human beings to diverse settings. The evolving society poses challenging conditions for humans, coupled with environmental problems. Therefore, it is critical to rely on scientific steps to generate new ideas to make life better.

*5.3. Relevance Scientific Enquiry Steps for Teachers*

For teachers, understanding scientific inquiry steps is critical. It offers a structured framework to enhance teaching methodologies. Experienced teachers' insights highlight the importance of this knowledge when selecting teaching methods. The perspectives shared by participants, emphasizing the role of scientific inquiry in refining pedagogical approaches:

*$R_1$: "Scientific inquiry helps me to provide enough evidence to justify my lessons in the classroom. We should not undervalue this in the teaching and learning environment.*

*$R_2$: "Sometimes it is difficult to apply scientific steps in teaching certain sensitive topics that society frowns upon. However, it is a beneficial approach to preparing achievable lessons."*

*$R_3$: "Scientific inquiry is evidence-based, which we most use to facilitate teaching and learning."*

*$R_4$: "I have been applying scientific inquiry when preparing to teach. It has been helpful in making my lessons really enrich the learning experience of my students."*

*$R_5$: "During teaching, my knowledge of scientific inquiry helps me test my methodologies to achieve my objectives."*

*$R_6$: "I used scientific inquiry to make lessons practical for my students. This has been helpful to me in achieving my aim over the years."*

*$R_7$: "There are challenges in teaching. The scientific inquiry steps have helped me manage most of the challenges, especially teaching methods and resources. "*

*$R_8$: "My knowledge of scientific inquiry helps me prepare teaching material from my environment. This in a way exposes my class to things around them. "*

*$R_9$: "I used scientific inquiry to make sure that I didn't deviate from my instructional objectives. Sometimes, it can be challenging, but it is the best way to acquire knowledge."*

*$R_{10}$: "As a researcher and a teacher, scientific inquiry assists in my teaching and research activities. In teaching, it helps me to study my student's needs and adopt appropriate teaching methods."*

The excerpt above presents the role of scientific inquiry in teaching and learning. The excerpt indicated that scientific steps offer a structural and systematic framework that facilitates teaching and learning. Notably, the application of observation, experimentation, and evidence-based learning by teachers, enhances the attainment of their instructional objectives. As a result, students seek to benefit from these profound learning experiences. Therefore, teachers and researchers in the teaching and learning environment, particularly in higher education, rely on this concept to achieve their goals.

### *5.4. Role of Technologies in Redefining Traditional Scientific Inquiry Steps*

This section presents data about how technologies are redefining traditional scientific inquiry steps. The next verbatim quotes are the perspectives of the respondents justifying this theme.

*$R_1$: "There are so many technologies out there that present unique approaches to research. Many are useful, so we can't run away from them."*

*$R_2$: "The world is advanced. All this is because of technology, which makes everything easier. The challenges we face in research have now diminished."*

*$R_3$: "The scientific field encompasses numerous useful technologies. Even though we have challenges procuring some of them, a few we have are useful. We need to manage and maintain them."*

*$R_4$: "Science and technology go together. I am happy with a few technologies in my faculty for their relevance. For example, in astronomy, telescopes can be used to see farther away. This helps in scientific investigation like many others."*

*$R_5$: "Emerging technologies that the world is currently experiencing are an opportunity for us to reshape our knowledge and skills. We can rely on them to come up with new findings in the scientific world."*

*$R_6$: "It utilizes technology. It helps to study the nature of people and how things happen in the modern world."*

*$R_7$: "Every sector uses technology today." In healthcare, technologies are used for treatments. I am also utilizing these technologies to accomplish my goal."*

*$R_8$: "We are in the age of technology, where everything can be facilitated by it. Even digitally, we can explore the cultures and societies around us without difficulty. So, it is a beneficial thing."*

*$R_9$: "I use technology almost every day. I use it in crafting teaching and materials for my students, and for collecting and analysing data for my research."*

*$R_{10}$: "Technologies have been helping me to study new things. It's also useful in breaking down complex concepts into simpler forms for understanding."*

The perspectives of the participants presented above show that technologies play a crucial role in promoting scientific inquiry across diverse fields. Researchers and scientists use technologies in various ways, including to learn and understand new concepts. It serves as a smart tool for facilitating easy access to information, a faster way of getting things done, developing research instruments, and enhancing data analysis. Astronomers have provided evidence of their use of technology for monitoring,


*ISSN: 2576-8484*
*Vol. 8, No. 5: 74-87, 2024*
*DOI: 10.55214/25768484.v8i5.1632*

and healthcare professionals can employ them for treatment. This is justifiable because, recent cutting-edge tools like AI, and nanotechnology, are helpful in making life easier for researchers. This seeks to change the paradigm of research in terms of approaches and methodologies for understanding and shaping the world.

## 6. Discussion

In this study, the researchers explored the processes of acquiring knowledge through the scientific inquiry steps. The findings indicated diverse strategies employed by researchers in higher education in South Africa to successfully maintain the scientific steps in solving problems. Among these strategies are the adoption of technologies in research methodologies and the fostering of collaborative efforts through interdisciplinary approaches. These results contradict [53] due to the challenges involved in interdisciplinary collaboration, but support [54] that the relevance of technology integration in scientific research cannot be underestimated.

We identified many technological tools that can facilitate data collection and analysis. For example, the use of AI, machine learning, and nanotechnology, was recommended. Canlas and Kazakbaeva [55] concur that interdisciplinary approaches are suitable in climate change education and further emphasise the collaborative approach to using technology in problem-solving. Additionally, Fatima and Pasha [56] support the integration of machine learning algorithms in the research process. This could be evidence showing the extent to which the scientific communities embrace novel technologies to expand understanding. The use of algorithms helps uncover complex relationships and phenomena. This overlooks and surpasses the traditional analytical methods. Also, Chen, et al. [57] support the interdisciplinary collaboration approach to problem solving. We can use it to enhance scientific methodologies and accomplish our objectives. Although challenges confronting research progress were found, like limited funding and infrastructure, Kulkarni [58] argues that effective communication, resource management, resilience, and adaptability strategies were essential for driving progress in scientific research.

Furthermore, research findings undergo continuous refinement and re-evaluation due to the cyclical nature of scientific inquiry. In this vein, Agyei-Mensah and Owusu [59] agree that constant re-assessment improves precision and comprehension in scientific fields. This justifies the importance of being resilient and remaining responsive to new ideas and evidence in the process of generating knowledge. According to Ofori-Boateng [60], new evidence was used to support and enhance the accuracy of their climate models. Therefore, we recommend that other researchers justify their predictions when generating knowledge.

Moreover, data about the relevance of the scientific inquiry steps to teaching pedagogy show that teachers can rely on this approach to enhance their instructional methods. We noted that teachers can plan effective lessons by applying structural scientific frameworks such as refining methods, embracing diverse perspectives, and revisiting hypotheses and experiments. Cochran-Smith and Lytle [61] disagree with this result, claiming teachers have inadequate knowledge of the application of scientific steps. However, McNerney and Hall [62] argue that scientific steps could also be applied in teaching early childhood education to build the scientific knowledge of learners. Therefore, teachers must be encouraged to embrace a scientific approach in order to be effective.

## 7. Conclusion

This study explores scientific inquiry, with a particular focus on using scientific steps to enhance instructional methods across disciplines in higher education. It can be established that researchers in South Africa advance through scientific inquiry by constantly refining their methods, incorporating diverse viewpoints, revisiting hypotheses, and conducting experiments to test them. Many researchers also leverage new technologies and collaborate across different disciplines to enrich their research. Effective communication, resource management, and adaptability are crucial skills in this process.

Scientists often innovate by exploring new directions and taking calculated risks, striving to perform optimally at each stage.

The nature of scientific inquiry is essential for learning, discovering, and acquiring knowledge. This ongoing process helps refine new ideas and make daily activities more reliable, demonstrating how humans can adapt to different environments. As society evolves and environmental challenges arise, relying on scientific methods to generate new ideas becomes vital for improving life. In education, scientific inquiry provides a structured framework that facilitates teaching and learning. Teachers use observation, experimentation, and evidence-based methods to achieve their teaching goals and offer students valuable learning experiences. This approach is particularly important in higher education, where both teachers and researchers rely on these methods to meet their objectives.

*7.1. Recommendations*

i. Higher education teachers and researchers, particularly those who do not have a science background, require regular professional training on the application of scientific methods in preparing instructions.
ii. Integration of modern technologies, such as AI, into teaching and research should be encouraged. Most of these technologies are appropriate for enhancing efficiency and effectiveness in teaching and research.
iii. Collaboration is critical to promoting research and learning. Therefore, seminars, conferences, and workshops for researchers and teachers across disciplines should be encouraged in higher education.
iv. We can conduct more evaluation studies to look into the efficacy of a different scientific approach to teaching research methods.

*7.2. Limitation*

i. The study gathered data from ten experienced researchers, particularly in the field of science education. Although this did not affect the outcome of the study, future studies should focus on investigating the level of knowledge of emerging researchers in a different discipline on scientific inquiry steps.

## Funding:

This study received no specific financial support.

## Institutional Review Board Statement:

The Ethical Committee of the University of Western Cape, South Africa has granted approval for this study on 31 August 2022 (Ref. No. HS21/6/23).

## Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

## Competing Interests:

The authors declare that they have no competing interests.

## Authors' Contributions:

Framing the title, writing the introduction, methodology, data analysis, and discussion of findings, K.N.M.; developed the theoretical framework, conducted the literature review, and collected data from the participants, B.P.Z.G. Both authors have read and agreed to the published version of the manuscript.

## References
[1] M. M. Noor, "'Which cup is the best?': Encouraging children to act like scientists when investigating the properties of materials," *Journal of Emergent Science*, vol. 26, pp. 5-15, 2024.
[2] J. Gyllenpalm, C.-J. Rundgren, J. Lederman, and N. Lederman, "Views about scientific inquiry: A study of students' understanding of scientific inquiry in grade 7 and 12 in Sweden," *Scandinavian Journal of Educational Research*, vol. 66, no. 2, pp. 336-354, 2022. https://doi.org/10.1080/00313831.2020.1869080
[3] C. Rees, R. Pardo, and J. Parker, "Steps to opening scientific inquiry: Pre-service teachers' practicum experiences with a new support framework," *Journal of Science Teacher Education*, vol. 24, pp. 475-496, 2013. https://doi.org/10.1007/s10972-012-9315-y
[4] S. Fortunato *et al.*, "Science of Science," *Science*, vol. 359, no. 6379, p. eaao0185, 2018. https://doi.org/10.1126/science.aao0185
[5] A. J. Trew *et al.*, "Can current science research in the biological sciences be used in primary school children's scientific enquiry?," *Journal of Biological Education*, vol. 57, no. 3, pp. 455-468, 2023. https://doi.org/10.1080/00219266.2021.1924229
[6] S. Rönnebeck, S. Bernholt, and M. Ropohl, "Searching for a common ground–A literature review of empirical research on scientific inquiry activities," *Studies in Science Education*, vol. 52, no. 2, pp. 161-197, 2016. https://doi.org/10.1080/03057267.2016.1206351
[7] P. Z. Buthelezi and K. Mpuangnan, "The Impact of integrating the history of science into life science teaching of viruses on students' comprehension of microbiology concepts," *International Journal of Innovative Technology and Interdisciplinary Sciences*, vol. 7, no. 1, pp. 1-14, 2024.
[8] J. Kranz, A. Baur, and A. Möller, "Learners' challenges in understanding and performing experiments: A systematic review of the literature," *Studies in Science Education*, vol. 59, no. 2, pp. 321-367, 2023. https://doi.org/10.1080/03057267.2022.2138151
[9] T. Moyo and S. McKenna, "Constraints on improving higher education teaching and learning through funding," *South African Journal of Science*, vol. 117, no. 1-2, pp. 1-7, 2021. https://doi.org/10.17159/sajs.2021/7807
[10] M. Monnapula-Mapesela, "Enabling and constraining causal powers for research and innovation in the South African higher education," *South African Journal of Higher Education*, vol. 38, no. 2, pp. 217-235, 2024. https://doi.org/10.17159/sajs.2021/7807
[11] M. N. G. Mtshali and R. Sooryamoorthy, "A research-inducing environment at a University of Technology in South Africa: Challenges and future prospects," *Futures*, vol. 111, pp. 194-204, 2019. https://doi.org/10.1016/j.futures.2018.06.017
[12] N. Taylor, "Inequalities in teacher knowledge in South Africa. South African schooling: The enigma of inequality," *South African Schooling: The Enigma of Inequality: A Study of the Present Situation and Future Possibilities*, pp. 263-282, 2019. https://doi.org/10.1007/978-3-030-18811-5_14
[13] K. Sommer, P. Kring, C. G. Strippel, and K. Emmerich, "Teaching and learning scientific inquiry–step by step," *CHEMKON*, vol. 29, no. 5, pp. 375-381, 2022. https://doi.org/10.1002/ckon.202000042
[14] P. J. Germann, "The inquiry" I": A tool for learning scientific inquiry," *The American Biology Teacher*, vol. 64, no. 7, pp. 512-520, 2002. https://doi.org/10.2307/4451356
[15] X. Tang, J. E. Coffey, A. Elby, and D. M. Levin, "The scientific method and scientific inquiry: Tensions in teaching and learning," *Science Education*, vol. 94, no. 1, pp. 29-47, 2010. https://doi.org/10.1002/sce.20366
[16] C. K. K. Chan and Y. Yang, *Developing scientific inquiry in technology-enhanced learning environments. In: Voogt, J., Knezek, G., Christensen, R., Lai, KW. (Eds.), Second Handbook of Information Technology in Primary and Secondary Education. Springer International Handbooks of Education.* Cham: Springer. https://doi.org/10.1007/978-3-319-53803-7_11-1, 2018.
[17] S. Minardi, R. Harris, and L. Labadie, "Astrophotonics: Astronomy and modern optics," *Astronomy and Astrophysics Review*, vol. 29, no. 1, p. 6, 2021. https://doi.org/10.1007/s00159-021-00134-7
[18] J. Newman, "Promoting interdisciplinary research collaboration: A systematic review, a critical literature review, and a pathway forward," *Social Epistemology*, vol. 38, no. 2, pp. 135-151, 2024. https://doi.org/10.1080/02691728.2023.2172694
[19] M. R. Islam, *Inquiry: A fundamental concept for scientific investigation. In: Islam, M.R., Khan, N.A., Baikady, R. (Eds.), Principles of Social Research Methodology.* Singapore: Springer. https://doi.org/10.1007/978-981-19-5441-2_1, 2022.
[20] A. Ford, *System dynamics models of environment, energy, and climate change. In: Dangerfield, B. (Eds.), System Dynamics. Encyclopedia of Complexity and Systems Science Series.* New York: Springer. https://doi.org/10.1007/978-1-4939-8790-0_541, 2020.

[21] K. Van Assche, R. Beunen, M. Duineveld, and M. Gruezmacher, "Adaptive methodology. Topic, theory, method and data in ongoing conversation," *International Journal of Social Research Methodology*, vol. 26, no. 1, pp. 35-49, 2023. https://doi.org/10.1080/13645579.2021.1964858

[22] M. L. Barnes *et al.*, "Social determinants of adaptive and transformative responses to climate change," *Nature Climate Change*, vol. 10, no. 9, pp. 823-828, 2020. https://doi.org/10.1038/s41558-020-0871-4

[23] E. Jockusch and K. Ober, "Hypothesis testing in evolutionary developmental biology: A case study from insect wings," *Journal of Heredity*, vol. 95, no. 5, pp. 382-396, 2004. https://doi.org/10.1093/jhered/esh064

[24] S. Datta, K. N. Rajnish, M. S. Samuel, A. Pugazlendhi, and E. Selvarajan, "Metagenomic applications in microbial diversity, bioremediation, pollution monitoring, enzyme and drug discovery. A review," *Environmental Chemistry Letters*, vol. 18, pp. 1229-1241, 2020. https://doi.org/10.1007/s10311-020-01010-z

[25] K. McNerney, D. Carritt, H. Dealey, and G. Ladbury, "Using a scientific enquiry framework, focusing on questions, to promote enquiry skills in early childhood," *Early Child Development and Care*, vol. 190, no. 1, pp. 30-42, 2020. https://doi.org/10.1080/03004430.2019.1653549

[26] G. Christakos, B. P., and S. M.L., *Scientific hypothesis testing, explanation, and decision making. In: Temporal GIS*. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-642-56540-3_8, 2001.

[27] P. K. Sahu, *Formulation and testing of hypothesis. In: Research Methodology: A Guide for Researchers in Agricultural Science, Social Science and Other Related Fields*. India: Springer. https://doi.org/10.1007/978-81-322-1020-7_9, 2013.

[28] J. D. Watson and F. H. Crick, "Molecular structure of nucleic acids: A structure for deoxyribose nucleic acid," *Nature*, vol. 171, no. 4356, pp. 737-738, 1953. https://doi.org/10.1038/171737a0

[29] K. Nuttavuthisit, *Data analysis and interpretation. In: Qualitative Consumer and Marketing Research*. Singapore: Springer. https://doi.org/10.1007/978-981-13-6142-5_10, 2019.

[30] W. Schmidt and M. Völschow, *Astronomical data analysis. In: Numerical python in astronomy and astrophysics undergraduate lecture notes in physics*. Cham: Springer. https://doi.org/10.1007/978-3-030-70347-9_5, 2021.

[31] G. Bammer, "What constitutes appropriate peer review for interdisciplinary research?," *Palgrave Communications*, vol. 2, no. 1, pp. 1-5, 2016. https://doi.org/10.1057/palcomms.2016.17

[32] R. R. Brown, A. Deletic, and T. H. Wong, "Interdisciplinarity: How to catalyse collaboration," *Nature*, vol. 525, no. 7569, pp. 315-317, 2015. https://doi.org/10.1038/525315a

[33] M. Wensing and C. Ullrich, *Dissemination and utilisation of research findings. In: Wensing, M., Ullrich, C. (Eds.), Foundations of health services research*. Cham: Springer, 2023.

[34] K. N. Mpuangnan, H. R. Mhlongo, and S. Govender, "Managing solid waste in school environment through composting approach," *Journal of Integrated Elementary Education*, vol. 3, no. 1, pp. 34-57, 2023. https://doi.org/10.21580/jieed.v3i1.16003

[35] R. S. Schwartz and B. A. Crawford, "Authentic scientific inquiry as context for teaching nature of science: Identifying critical element in scientific inquiry and nature of science: Implications for teaching, learning, and teacher education." Dordrecht: Springer Netherlands, 2006, pp. 331-355.

[36] D. Tsybulsky, "Comparing the impact of two science-as-inquiry methods on the NOS understanding of high-school biology students," *Science & Education*, vol. 27, no. 7, pp. 661-683, 2018. https://doi.org/10.1007/s11191-018-0001-0

[37] J. Byrne, W. Rietdijk, and S. Cheek, "Enquiry-based science in the infant classroom:'letting go'," *International Journal of Early Years Education*, vol. 24, no. 2, pp. 206-223, 2016. https://doi.org/10.1080/09669760.2015.1135105

[38] K. N. Mpuangnan, "Determining skills of basic schoolteachers in test item construction. Review of Education." 12(2), e3478., 2024. https://doi.org/10.1002/rev3.3478

[39] K. N. Mpuangnan and S. Padhan, "Overview of Curriculum Development Stages," *Educational Quest-An International Journal of Education and Applied Social Sciences*, vol. 10, no. 3, pp. 141-148, 2019.

[40] F. Jiang and W. F. McComas, "The effects of inquiry teaching on student science achievement and attitudes: Evidence from propensity score analysis of PISA data," *International Journal of Science Education*, vol. 37, no. 3, pp. 554-576, 2015. https://doi.org/10.1080/09500693.2014.1000426

[41] B. A. Crawford, "Embracing the essence of inquiry: New roles for science teachers," *Journal of Research in Science Teaching*, vol. 37, no. 9, pp. 916-937, 2000. https://doi.org/10.1002/1098-2736(200011)37:9%3C916::aid-tea4%3E3.3.co;2-u

[42] L. Ann Haefner and C. Zembal-Saul, "Learning by doing? Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning," *International Journal of Science Education*, vol. 26, no. 13, pp. 1653-1674, 2004. https://doi.org/10.1080/0950069042000230709

[43] N. Angrist *et al.*, "Building back better to avert a learning catastrophe: Estimating learning loss from COVID-19 school shutdowns in Africa and facilitating short-term and long-term learning recovery," *International Journal of Educational Development*, vol. 84, p. 102397, 2021. https://doi.org/10.1016/j.ijedudev.2021.102397

[44] P. Adorno, Dominique, N. Pizzolato, and C. Fazio, "Long term stability of learning outcomes in undergraduates after an open-inquiry instruction on thermal science," *Physical Review Physics Education Research*, vol. 14, no. 1, p. 010108, 2018. https://doi.org/10.1103/physrevphyseducres.14.010108

[45] R. Aslam, N. Khan, M. M. Asad, and U. Ahmed, "Impact of technological pedagogical content knowledge on teachers' digital proficiency at classroom in higher education institution of Pakistan," *Interactive Technology and Smart Education*, vol. 18, no. 1, pp. 119-130, 2021. https://doi.org/10.1108/itse-11-2020-0222

[46] T. Li *et al.*, "CRISPR/Cas9 therapeutics: Progress and prospects," *Signal Transduction and Targeted Therapy*, vol. 8, no. 1, p. 36, 2023. https://doi.org/10.1038/s41392-023-01309-7

[47] V. Sood and R. P. Chauhan, "Archives of quantum computing: Research progress and challenges," *Archives of Computational Methods in Engineering*, vol. 31, no. 1, pp. 73-91, 2024. https://doi.org/10.1007/s11831-023-09973-2

[48] G. S. Maxwell, *Interpreting data: Creating meaning. In: Using Data to Improve Student Learning. The Enabling Power of Assessment*. Cham: Springer, 2021.

[49] K. Parti and A. Szigeti, "The future of interdisciplinary research in the digital era: obstacles and perspectives of collaboration in social and data sciences-an empirical study," *Cogent Social Sciences*, vol. 7, no. 1, p. 1970880, 2021. https://doi.org/10.1080/23311886.2021.1970880

[50] K. S. Taber, *Constructivism in education: Interpretations and criticisms from science education. In Early childhood development: Concepts, methodologies, tools, and applications* Hershey, Pennsylvania: IGI Global. https://doi.org/10.4018/978-1-5225-7507-8.ch015, 2019.

[51] K. E. Willcox, S. Sarma, and P. H. Lippel, *Online education: A catalyst for higher education reforms*. Cambridge: Massachusetts Institute of Technology, 2016.

[52] L. R. Gay, M. G. E., and A. P., *Educational research: Competencies for analysis and applications*, 10th ed. Upper Saddle River: Pearson Education, Inc, 2012.

[53] J. L. Lanterman and S. J. Blithe, "The benefits, challenges, and disincentives of interdisciplinary collaboration," *Commoning Ethnography*, vol. 2, no. 1, pp. 149-165, 2019.

[54] N. Ameen, S. Hosany, and A. Tarhini, "Consumer interaction with cutting-edge technologies: Implications for future research," *Computers in Human Behavior*, vol. 120, p. 106761, 2021. https://doi.org/10.1016/j.chb.2021.106761

[55] I. P. Canlas and R. Kazakbaeva, *Interdisciplinary approach to climate change education. In: Leal Filho, W., Sima, M., Lange Salvia, A., Kovaleva, M., Manolas, E. (Eds.), University Initiatives on Climate Change Education and Research*. Cham: Springer, 2023.

[56] M. Fatima and M. Pasha, "Survey of machine learning algorithms for disease diagnostic," *Journal of Intelligent Learning Systems and Applications*, vol. 9, no. 1, pp. 1-16, 2017. https://doi.org/10.4236/jilsa.2017.91001

[57] D. Chen, W. Huang, Y. Wang, and Y. Chang, "Training for interdisciplinary collaboration in environmental planning: The shore-land project, Taiwan," *Planning Practice & Research*, vol. 37, no. 4, pp. 464-483, 2022. https://doi.org/10.1080/02697459.2021.2023987

[58] M. Kulkarni, "What are the research challenges that academic researchers face, and how dothey overcome them?," *Academia Letters, Article 1509*, 2021. https://doi.org/10.20935/AL1509

[59] S. Agyei-Mensah and G. Owusu, "Challenges of environmental health governance in developing countries: Lessons from Ghana," *International Journal of Environmental Research and Public Health*, vol. 15, no. 4, pp. 1-18, 2018.

[60] C. Ofori-Boateng, "Advancements in climate modeling: Implications for predicting future trends in Ghana," *Climate Dynamics*, vol. 35, no. 2, pp. 210-225, 2021.

[61] M. Cochran-Smith and S. L. Lytle, "Research on teaching and teacher research: The issues that divide," *Educational Researcher*, vol. 19, no. 2, pp. 2-11, 1990. https://doi.org/10.2307/1176596

[62] K. McNerney and N. Hall, *Developing a framework of scientific enquiry in early childhood: An action research project to support staff development and improve science teaching. In Early Years Science Education*, 1st ed. London: Routledge, 2020.