Pre-service teachers' use of science process skills in understanding biological concepts based on plant taxonomy at a Nigerian University.

By

Adekemi Oreoluwa Odukoya

Student No: 219091687

A dissertation submitted in fulfilment of the academic requirements for the degree of Doctor of Philosophy in Science Education, School of Education

University of KwaZulu-Natal

Edgewood Campus

Supervisor: Dr. Leonard Molefe

February 2024

Abstract

Despite the widespread acknowledgement of the significance of science process skills (SPS) in science education, research indicates a persistent deficiency in the use of SPS among pre-service teachers, particularly in the domain of biological concepts related to plant taxonomy. This investigation aimed to fill this gap by studying how pre-service teachers utilize SPS in comprehending biological concepts based on plant taxonomy within a Nigerian University. The study had three primary objectives: firstly, to explore pre-service teachers' conceptual knowledge of SPS and their level of biology literacy; secondly to explore how pre-service teachers use SPS to understand biological concepts based on plant taxonomy; and thirdly, to investigate the factors influencing pre-service teachers' use of SPS in to understand biological concepts based on plant taxonomy.

The research adopted a qualitative method, using open-ended questionnaires, focus group interviews (FGIs), and cogenerative dialogue to collect data. The open-ended questionnaires were employed to gain insight into the participants' understanding of SPS, facilitating in-depth data collection and exploration of their viewpoints. FGIs were utilized to gather qualitative data, enabling participants to candidly share their experiences, preferences, and challenges. Cogenerative dialogue facilitated an open discussion for pre-service teachers to articulate the factors they perceive as barriers to utilizing SPS in comprehending plant taxonomy. A pilot study was conducted to assess the research instruments and confirm their suitability. The research design and data collection methods were geared towards ensuring the robustness and reliability of the research outcomes. Additionally, ethical considerations were carefully addressed, including obtaining research authorization, gaining participant data collection approval, maintaining confidentiality and privacy, ensuring data accuracy, and handling data use and disposal.

The study was grounded in two key theoretical frameworks: Cultural-Historical Activity Theory (CHAT) and Biological Literacy. CHAT informed the understanding of the significance of social facets of learning and the development of skills like SPS. The study used CHAT to explore how the pre-service teachers, as learners, interacted with their environment, to use SPS to understand biological concepts based on plant taxonomy. Biological Literacy was also employed to explore the level of biological literacy among the pre-service teachers and how it related to their understanding and utilisation of SPS in the context of plant taxonomy.

Participants in the study consisted of 24 pre-service biology teachers who were in their third and fourth academic years at a Nigerian University. The participants were chosen because of their extensive experience (of at least 3 years) in the development of SPS.

The findings revealed that pre-service teachers demonstrated a solid understanding of some SPS, such as classifying, measuring, and interpreting data. However, they struggled with other skills, such as operational definition, identifying and controlling variables, hypothesising and predicting. Pre-service teachers' level of biological literacy was found to be relatively low, with many struggling to apply scientific knowledge in decision-making, particularly in the context of plant taxonomy. The study also revealed that practical work (PW) was an essential component of science education, but pre-service teachers often lack the necessary skills and training to effectively implement PW in their learning of SPS . Furthermore, the study identified external factors, such as financial constraints, difficulties in plant identification, and the availability of qualified instructors, as potential barriers to the development of SPS among pre-service teachers.

The study concluded that pre-service teachers exhibited deficiencies in their understanding and application of SPS, particularly in the context of plant taxonomy-based biological concepts. The study underscored the broader implications for the education system's ability to cultivate essential SPS among pre-service biology teachers. The inadequacies observed, despite prior exposure to SPS concepts, underscored a critical gap in foundational understanding. This deficiency not only hinders pre-service teachers' capability to effectively teach and communicate these concepts but also raises questions about the adequacy of current pedagogical approaches and the need for targeted interventions.

Keywords: Pre-service teachers, Plant taxonomy, Science Process Skills, Biological Literacy, CHAT, Science education, teacher professional development.

Declaration

I, Adekemi Oreoluwa Odukoya, declare as follows:

i. Except in cases where it is stated differently, the research presented in this thesis is my own.
ii. This thesis has not yet been sent to another university for assessment or degree consideration.
iii. Except as indicated, no data, images, graphs, or other information from other people is used in this thesis unless it is properly attributed to them.
iv. No portion of this doctoral thesis is written by another individual unless indicated as originating from other researchers. Whenever textual sources are cited, then:
    a. Their statements have been paraphrased, while still crediting them for the general information conveyed.
    b. Their writing has been referenced appropriately.
v. The research detailed in this dissertation was conducted at the School of Education, University of KwaZulu-Natal, from January 2020 to February 2024 under the guidance of Dr. Leonard Molefe (Supervisor).
vi. The Ethical Clearance Reference No. HSSREC/00003213/2021 was granted before undertaking the fieldwork.

[redacted]

Adekemi Oreoluwa Odukoya

Date: 28/08/2024

[redacted]

Dr. Leonard Molefe

Dedication

I dedicate this dissertation to my family, including my parents, spouse, and children. I extend my gratitude for your love, assistance, and motivation throughout my pursuit of this degree. I hold you all dear.

Acknowledgements

I express my profound appreciation to God almighty who has made it possible for me to attain this academic height. Your love, mercy and grace have kept me throughout this journey. I could not have accomplished this work without you, Lord. I am grateful.

My supervisor, Dr. Leonard Molefe, thank you so much for your endless patience, continuous support and encouraging effort. Thank you for continually pushing me to go above and beyond and shaping the direction of my study. I have learnt a lot from you during this programme.

My appreciation also goes to the Tertiary Education Trust Fund (TETFUND) and the management of Adekunle Ajasin University for their financial support towards the fulfilment of this degree.

I would also love to say a very big thank you to my husband, Prince Taiwo Odukoya, for your support, love, care, encouragement, perseverance, and moral support throughout this PhD journey. Thank you for your understanding and always helping out with the kids so that I was not too overwhelmed with the programme and being a mom. You are indeed one in a million.

To my lovely princes, Adekinte and Adesunmibare Odukoya, you boys are the best. Thank you for your understanding on days mummy would need to study and you had to stay with daddy. I pray your future will be bright in Jesus' name.

Besides, my appreciation goes to my parents, Mr and Mrs Adewumi, thank you for being my rock, my support, and my advisers. You both have been there with me throughout this journey. I pray you reap the fruits of your labour in Jesus' name. To my siblings, Gbenga, Seye and Itunu Adewumi, I could not have wished for better siblings than you guys. Thank you all for your support one way or the other. I would also like to say a big thank you to my in-laws for your concerns and support.

To my colleague-turned-friend, Dr. O.S Aboderin, thank you very much for your words of encouragement, guidance and contributions towards this study. You have been of good help to me right from the beginning until the end of this thesis. You are indeed one of a kind and I truly appreciate all you did for me.

Ultimately, I extend my gratitude to all the individuals who participated in this study. Your involvement was instrumental, and I truly appreciate the time and effort you contributed. I am deeply thankful. I also want to express my appreciation to my friends and family who have supported me throughout my PhD journey, whether through direct contributions or by regularly inquiring about my progress. I am grateful for your invaluable support. I regret that I cannot mention each of you by name.

Glossary of Acronyms and Abbreviations

AR - Augmented Reality

BL - Biological Literacy

BSPS - Basic Science Process Skills

CD - Could Define

CND - Could Not Define

CESAC - Comparative Education Study and Adaptation Centre

CHAT - Cultural-Historical Activity Theory

CI - Cooperative Inquiry

COGENS - Cogenerative Dialogue

FGI - Focus Group Interview

FME - Federal Ministry of Education

FRN - Federal Republic of Nigeria

HSSREC - Human and Social Science Ethics Committee

ISPS - Integrated Science Process Skills

NERDC - Nigerian Educational Research and Development Council

NERC - Nigeria Educational Research Council

NISP - Nigerian Integrated Science Project

NPE - National Policy on Education

NSSP - Nigeria Secondary School Science Project

PAR - Participatory Action Research

PCK - Pedagogical Content Knowledge

PIP – Participatory Inquiry Paradigm

PST - Preservice Teachers

PW - Practical Work

SAN - Science Association of Nigeria

SPS - Science Process Skills

STAN - Science Teachers Association of Nigeria

TP – Transformative Paradigm

TPCK - Technological Pedagogical Content Knowledge

Table of Contents

Table of Figures

List of Tables

Chapter One: Introduction

1.1 Introduction

Biological literacy and the knowledge of science process skills (SPS) of Nigerian pre-service teachers are crucial in their ability to appreciate and teach biology especially on plant taxonomy (Asy'ari et al., 2019). This study thus explores these aspects in terms of how they (pre-service teachers) use SPS in understanding biological concepts, and the factors that affect their learning and teaching of these concepts thereof.

This chapter provides an overview of the research topic's background and justification, emphasizing the importance of science education, specifically emphasising SPS related to plant taxonomy. Additionally, it outlines the study's objectives, explains the rationale behind the research, and highlights the gap in the current literature regarding pre-service teachers and their use of SPS in understanding biological concepts.

Additionally, it presents the rationale for the research and underscoring the gap found in the current literature concerning pre-service teachers and their application of SPS in biological concepts. The section also encompasses the research questions and elucidates essential concepts and terms featured in the study. Lastly, it underscores the research design, the study's constraints, and a preview of forthcoming chapters, offering a guide for the reader.

1.2 Background and Rationale

Science education is aimed at nurturing the development of SPS, a vital component that equips students with abilities applicable in their everyday lives (Panoy, 2013). It is believed that science education acts as a powerful mechanism for progress and advancement in nations worldwide (Osarenren-Osaghae & Irabor, 2018). This approach is viewed as a means of acquiring skills, important knowledge, and behaviours, while also instilling social values necessary for thriving in a dynamic world (Oyelola, 2015). The Federal Government of Nigeria (FRN) similarly asserts that science education serves as a tool for driving national development (FRN, 2013).

Nyakiti et al. (2010) propose that the science curriculum should function as a tool for cultivating SPS and fostering scientific mindsets. This suggests that SPS could form the basis for enquiry-based learning and should be an essential consideration in lesson planning.

The National Policy on Education (NPE) in Nigeria is designed to encourage the study of science, aiming to produce an ample number of scientists who can contribute to national progress (Akani, 2015). The Federal Republic of Nigeria (FRN, 2004) stresses the significance of imparting science processes and principles within the framework of the NPE (Bassey & Amanso, 2017). The Nigerian Educational Research and Development Council (NERDC) has advocated for the cultivation of SPS by moving from knowledge-based to activity-based teaching and learning techniques (National Association for Research in Science Teaching: NARST, 2011; Yumusak, 2016). Unfortunately, Nigerian students often have underdeveloped SPS due to a lack of exposure to practical science activities (Idiege et al., 2017). To bolster the development of SPS, the science content being taught in classrooms should be leveraged to enable pre-service educators to merge skills, knowledge, and attitudes for a comprehensive understanding of scientific concepts (Zeidan & Jayosi, 2015).

SPS are characterised as the abilities employed by scientists to construct knowledge, solve problems, and derive conclusions (Fugarasti et al., 2019). According to Karamustafaoglu (2011), SPS are essential skills or capabilities that scientists must possess during the process of scientific discovery. Conversely, Obialor (2016) defines SPS as activities employed by scientists in conducting scientific investigations to gain new knowledge. According to Omigbodun et al. (2010), SPS, which stands for Science and Problem-Solving skills, include both mental and physical capabilities and competencies. These competencies are vital instruments for effectively engaging with science and technology, as well as tackling challenges for individual and societal advancement. Considering these viewpoints, SPS can be regarded as competencies incorporated within scientific pursuits, rendering them indispensable for pre-service educators to possess. Educating these competencies to science students is critical for shaping their future, nurturing scientific mindsets such as inquisitiveness, creativity, and eagerness for exploration. Mastering SPS is not only crucial for instilling a scientific ethos among learners but also bears importance for societal progress.

The biology syllabus is designed to provide students with fundamental comprehension of critical biology concepts and to nurture practical competencies such as analytical thinking, communication, and problems solving (FME, 2008). This research centers on the biological topic of plant taxonomy, a customary element of higher education programs. This concept encompasses activities such as plant identification, description, classification, and naming. Proficiency in these tasks requires pre-service teachers to possess specific skills. By employing effective teaching approaches in science classrooms, educators can foster the expansion of SPS within the realm of plant taxonomy. Therefore, teachers should recognise the crucial role these skills play in science learning, acting as a foundation for the cultivation of cognitive abilities like logical thinking, reasoning, and problem-solving skills.

Developing educational policies is a government initiative to determine the direction of the educational system. Following the objectives outlined in the NPE, the FRN (2013) underscores that students can acquire diverse skills, including critical thinking skills, SPS, and problem-solving skills only when Nigerian tertiary institutions offer quality teaching and learning experiences with a curriculum that aligns with the demands of the labour market. This emphasises the importance of teachers possessing an in-depth understanding of SPS for effective teaching. Moreover, students should be able to cultivate these skills through exposure to them. As noted by Miles (2010), teachers equipped with ample SPS can deliver effective instruction, leading to enhanced performance by their students. When students are exposed to practical skills, as stated in the goals of the NPE, they will have practical knowledge that will be relevant in society, which will make them employable in the community as well as being self-employed. SPS play a crucial role in addressing scientific problems, aligning with the national goal of education in Nigeria. The Federal Government argues that education should facilitate the acquisition of relevant skills, abilities, and competencies by students (Ghumdia, 2016). To achieve this objective, the government instituted entities such as the Science Teachers Association of Nigeria (STAN) and the Nigerian Integrated Science Project (NISP). These organisations are tasked with evaluating the diverse curricula implemented across different levels of the Nigerian educational system.

Educators are tasked with emphasising the impartation of science skills, factual knowledge, concepts, and theories, fostering an environment where learners engage in scientific enquiry (Zeidan & Jayosi, 2015). Erkol and Ugulu (2014) argue that, within the teaching and learning process, science teachers should acquire SPS to enhance their students' proficiency. Maintaining positive attitudes is equally significant; as noted by Zeidan and Jayosi (2015), a favourable attitude towards science makes the learning experience more engaging, contributing to a heightened focus on developing SPS.

For students to know they are learning to acquire SPS, teachers should always guide these students when carrying out experiments (Rauf et al., 2013). Teachers bear the responsibility of fostering positive attitudes towards science among students, preparing them to thrive in a society dominated by science and technology. The trajectory of our society hinges on individuals who possess the ability to grasp and influence the intricate consequences of science and innovation on our global landscape (Ungar, 2010). To this effect, pre-service teachers need to develop SPS as this will enable them to use these skills to understand plant taxonomy. The participants for this study were drawn from 24 pre-service biology teachers in their third and fourth year respectively teachers in the University under study.

This study explored how pre-service teachers use SPS to understand plant taxonomy, and to be able to do this, I examined the understanding of SPS among pre-service teachers, explored the factors shaping their utilisation of SPS, and investigated how they apply SPS to comprehend biological concepts, specifically within the context of plant taxonomy.

The aim of advanced learning in Nigeria, as outlined in the National Policy on Education (NPE), is to address the country's requirements (Adebisi, 2014). According to the FRN (2013, p. 26), tertiary institutions should practise quality teaching and learning. Although it is not well stated in the policy that teachers should expose their students to SPS during teaching, for quality teaching to be practised by teachers, they are supposed to know SPS.

The impetus for undertaking this study originated from my firsthand experiences as an educator. Over the last three years, I have been instructing biology to pre-service teachers at a Nigerian university. I observed that most of my students who are pre-service teachers offering biology do not use SPS to understand biological concepts (plant taxonomy) despite being exposed to these SPS by their lecturers. These pre-service teachers' performance in biology classes and practical activities is not encouraging even though their lecturers have adopted various pedagogical strategies to enable the pre-service teachers to understand what they were (and are) being taught. The above reason prompted me to conduct this study in order to understand better how pre-service teachers use SPS in tandem with understanding biological concepts.

Multiple research endeavours in Nigeria have delved into SPS (Akinbobola & Afolabi, 2010; Kamba et al., 2018; Obialor et al., 2017). Akinbobola and Afolabi (2010) investigated SPS within the context of practical physics examinations for the West African senior secondary school certificate. Their study revealed that basic process skills outweighed integrated process skills in these examinations. Kamba et al. (2018) examined the relationship between SPS and student attitudes towards physics in senior secondary schools within the Aliero metropolis, uncovering an insufficiency in students' SPS knowledge, potentially stemming from inadequate exposure. In contrast, Obialor et al. (2017) explored the influence of project work on the acquisition of SPS among secondary school students in biology. The results displayed a significant positive impact, indicating that the teaching strategy and students' project work considerably enhanced SPS acquisition in biology.

Drawing from the several studies explored above on SPS in Nigeria, most of the studies conducted are on secondary school students. This indicates that, debatably, there is a scarcity of literature addressing research on pre-service teachers and their utilisation of SPS in comprehending biological concepts related to plant taxonomy in Nigerian universities. This study aimed to address this gap in the existing literature.

1.3 Statement of the Problem

Contemporary teaching of science demands that students be actively engaged in the teaching and learning process, with an emphasis on understanding scientific concepts and skills, such as SPS (Irwanto et al., 2018). For Coil et al. (2010), SPS "provide the tools and ways of thinking that enable students to build the robust conceptual frameworks needed to gain expertise in the Life Sciences" (p. 533). The achievement of the highest level of acquisition of SPS remains a challenge not only for lower school grades (Tilakaratne & Ekanayake, 2017) but also for teachers themselves (Aydoğdu, 2015) or senior students (Silay & Çelik, 2013). Despite the recognition of their importance at undergraduate level, insufficient time is spent developing them (Coil et al., 2010). In this study, I chose to focus on plant taxonomy rather than other biology topics due to its intrinsic complexity and the diverse skills required to become proficient in it. In contrast to other disciplines in biology, plant taxonomy demands a thorough comprehension of an intricate classification system as well as the integration of laboratory and field skills. As a lecturer in the department where this study was conducted, I have observed that pre-service teachers consistently perform poorly in plant taxonomy. This observed difficulty emphasizes how important it is to look into plant taxonomy to help pupils overcome these obstacles. Furthermore, although there are publications on SPS (e.g., Omigbodun et al., 2010; Kamba et al., 2018), there are limited studies on the use of SPS in understanding biological concepts based on plant taxonomy in Nigerian Universities. Lack of these few studies in this area can lead to misconceptions about plant taxonomy, causing students to perceive it as difficult. This study aims to address and correct these misconceptions.

I decided to conduct this study to explore the SPS of Nigerian biology pre-service teachers. SPS play a major role in the development of scientific concepts. Thus, while a conceptual understanding of SPS is important (Shahali et al., 2015), the associated biology concepts developed are equally important. The study investigated, drawing from a holistic understanding of the teachers' views, the present teachers' levels of biological literacy and, most importantly, whether their use of SPS did indeed enable them to understand biological concepts within the context of plant taxonomy. As context is important, it is essential that the study also investigates the basis for the teachers' views regarding the main focus of the study. Specifically, it examines whether their use of SPS enable them to understand biological concepts within the context of plant taxonomy.

1.4 The Purpose of the Study

This research sought to understand how pre-service educators at a Nigerian University apply Science Process Skills (SPS) in comprehending biological concepts. As most Higher Learning Institutions have no formal curriculum for teaching their students SPS, there is a need for relevant and effective pedagogical philosophies, methods and materials to teach these skills (Coil et al., 2010). The issue of biological literacy (Uno & Bybee, 1994) needs to be addressed as well if we intend to mould a well-rounded biology teacher. Thus, this study explored the development of the teachers' biological concepts of plant taxonomy (using the biological literacy model) and SPS (using indicators of the development of SPS) within the context of a methodological framework – action research – in tandem with cogenerative dialogue (cogens).

The aims of this study are:

1. To explore pre-service teachers'
    a. conceptual knowledge of SPS.
    b. Level of biology literacy
2. To explore how pre-service teachers use SPS to understand biological concepts based on plant taxonomy.
3. To investigate the factors that influence pre-service teachers' use of SPS to understand biological concepts based on plant taxonomy.

1.5 Research Questions

The study was guided by the following research questions:

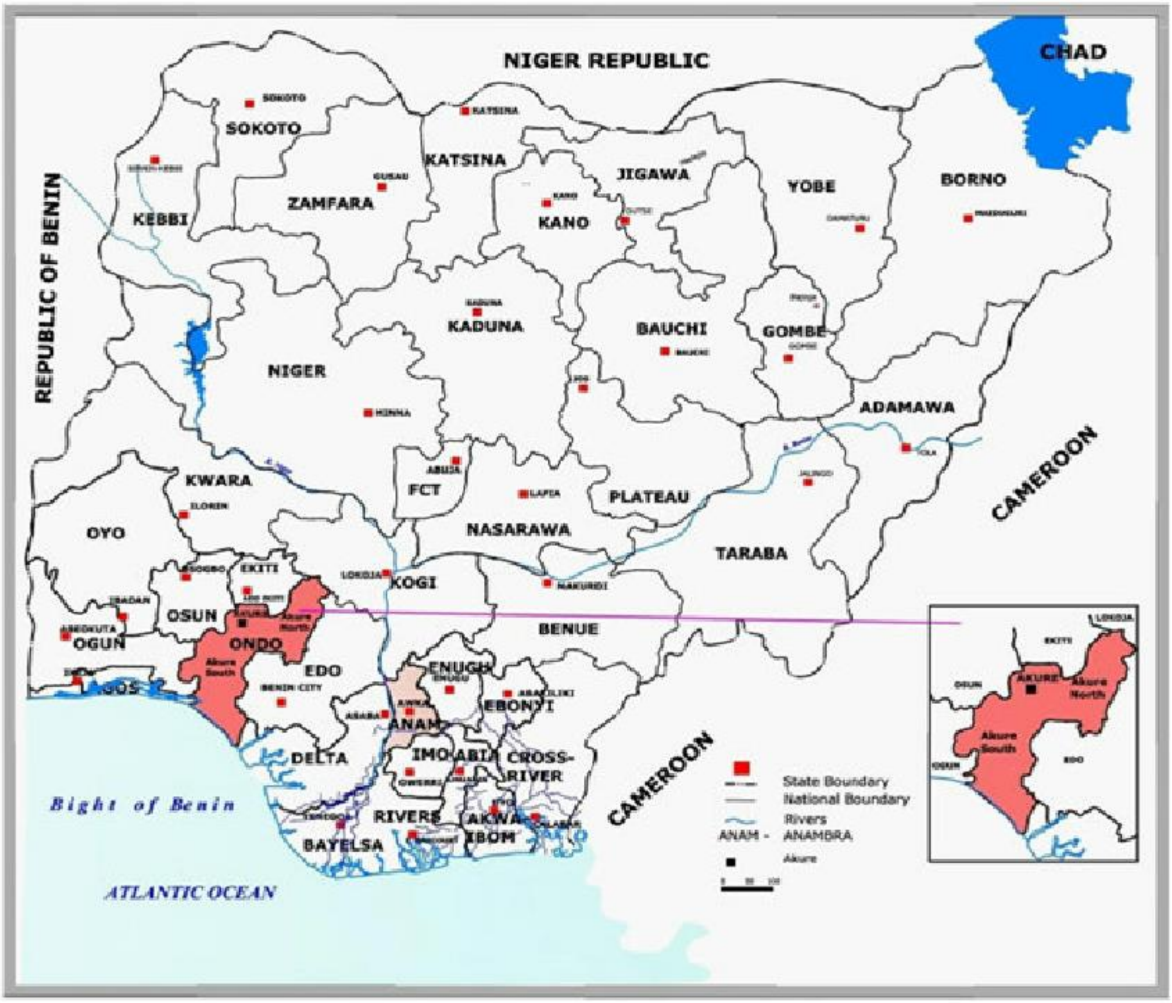
1) What are the pre-service teachers':
    a) conceptual knowledge of SPS?
    b) level of biology literacy?
2) How did pre-service teachers use SPS to understand biological concepts based on plant taxonomy?
3) Which factors influenced pre-service teachers' use of SPS to understand biological concepts based on plant taxonomy?

1.6 Location of Study

The study took place at Adekunle Ajasin University located in Ondo State, Nigeria, situated in the Southwestern region of the country. Nigeria, positioned on the West coast of Africa, has a population exceeding 200 million. The university comprises six faculties, including Agriculture, Arts, Education, Law, Science, and Social and Management Sciences. More specifically, this research was conducted within the Department of Science Education and the Faculty of Science, which are the main areas where aspiring teachers pursue Biology studies at the university. My motivation for conducting this study at this University stems from my deep interest in understanding why the pre-service teachers in my department struggle with plant taxonomy. Throughout my time here, I have observed that many students consistently perform poorly in this topic, this underachievement has sparked my curiosity and has driven me to explore underlying factors contributing to these challenges.

Figure 1.1

Map of Nigeria showing Ondo States.



Note. Adapted from *Socioeconomic factors affecting household's sanitation preferences in Akure* by Rotowa et al., 2015, p. 186.

1.7 Concepts/Terms of the Study

Several concepts and/or terms were clarified in this section within the context of the present research study. These included SPS, biological literacy, cultural-historical activity theory, cogenerative dialogues, and practical work all of which were part of the study's conceptual frameworks.

1.7.1 *Theoretical Framework*

Theoretical frameworks usually provide a blueprint of what research studies seek to achieve. As the present study needed to be situated in several conceptual and theoretical perspectives embedded in the literature to present a holistic understanding of the Nigerian pre-service teachers' use of SPS to understand plant taxonomy-based concepts, it was important that their level of Biological Literacy (BL), their Science Process Skills (SPS) and elements of Cultural-Historical Activity Theory (CHAT) (as well as cogenerative dialogues [cogens) were integrated to provide the need empirical evidence. The frameworks thereof are further described in Chapter 3.

1.7.2 *Congenerative Dialogue*

For Tobin (2014), cogens of a critical pedagogy process allow all participants to express their perspectives. Cogen set of rules can govern how they are used within an activity system, which enables them to fit in the exploration of "how learning opportunities are transformed by the collaborative efforts of instructors and students to improve the learning environment" as in CHAT (Jones, 2014). In this study, the cogens were used as both methodological procedures for generating data and as a mechanism to improve the researcher's Pedagogical Content Knowledge (PCK).

1.7.3 *Cultural-Historical Activities CHAT*

Cultural-Historical Activity Theory (CHAT) is a theoretical framework used to understand how learning opportunities are transformed through collaborative efforts in educational settings. It involves the allocation of labour among educators and class interaction through the use of cogens, promoting respect, equity, and diversity in dialogue (Murphy & Carlisle, 2008). CHAT prioritises collective growth over individual growth, emphasising the role of discourse and power in interacting activity systems.

1.7.4 *Biological Literacy (BL)*

Biological literacy includes both comprehending biological ideas as well as being able to employ scientific information to facilitate decision-making. It involves understanding biological diagrams, conceptual knowledge of SPS, and the ability to relate biology to other disciplines and society. Effective biology teaching and learning require a strong foundation in biological literacy (Mulbar &Bahri, 2021).

1.7.5 Practical Work (PW)

Practical Work (PW) is an essential component of science education that provides students with hands-on experience in scientific enquiry and experimentation (Akuma & Callaghan, 2019). It is a crucial aspect of developing SPS and promoting biological literacy. However, pre-service teachers often lack the necessary skills and training to effectively implement PW in their teaching.

1.7.6 Science Process Skills (SPS)

Science process skills (SPS) are essential competencies necessary for scientific investigation and comprehension of biological principles (Maranan, 2017. They encompass fundamental SPS (BSPS) such as observation, measurement, and communication, as well as Integrated Science Process Skills (ISPS) like hypothesis formulation, experimentation, and data interpretation. Mastery of SPS is crucial for students engaging in scientific pursuits (Zeidan & Jayosi, 2015).

1.8 The Study's Research Design

The research designs that guided this study were case study and participatory action research, utilizing a qualitative research approach. Participants in the study were selected using purposively sampling technique, and they were all third- and fourth-year pre-service biology teachers.

1.9 Delimitation of the Study

This study is confined to undergraduate students majoring in Biology education during their third and fourth years at a university in the southwestern region of Nigeria.

1.10 Overview of Chapters

Chapter 1 introduces the purpose, objectives and rationale for the study on pre-service teachers' use of SPS.

Chapter 2 reviews the literature on SPS, biological literacy and pre-service teachers' development of these skills.

Chapter 3 discusses the theoretical framework, including the Cultural-Historical Activity Theory (CHAT) and their relationship to biological literacy.

Chapter 4 explains the research methodology, including data collection and analysis used in the study.

Chapter 5 presents the findings of the study on pre-service teachers' use of SPS and biological literacy.

Chapter 6 delves into the study's findings and their impact on the application of SPS among pre-service teachers. It also scrutinizes the study's constraints and proposes potential areas for future research.

1.11 Summary of Chapter

Chapter One introduces the research on biological literacy and SPS among Nigerian pre-service teachers, with a specific focus on plant taxonomy. The chapter outlines the significance of science education in fostering SPS and emphasises the importance of SPS for addressing educational gaps. Adekunle Ajasin University in Ondo State, Nigeria, serves as the research location, with an emphasis on the Faculties of Education and Science. The study's objectives include exploring pre-service teachers' conceptual knowledge of SPS, their biology literacy level, and how they apply SPS to understand plant taxonomy. The research design involves an action research methodology and cogenerative dialogues. Key concepts such as SPS, biological literacy, Cultural-Historical Activity Theory (CHAT), and practical work are defined. The chapter concludes by delineating the scope of the study, focusing on third- and fourth-year pre-service biology teachers in a southwestern Nigerian university. Overall, Chapter One establishes the groundwork for the investigation, providing a comprehensive overview of the research context, objectives, and key concepts.

Chapter Two: Review of Literature

2.1 Introduction

This chapter is focused on research and literature embedded in SPS and biological literacy. This is important because there is an argument that biologically literate persons should not only understand biological principles and key biological concepts but also the methods used in scientific research. SPS are the heart of the scientific enquiry. Thus, the section reviewed pre-service teachers' development of SPS. As the argument above also points to the interplay between these skills (SPS) and biological literacy, the further focus was on debates associated with SPS in the generation of biological knowledge using scientific enquiry.

The review of literature and research comprised two main parts. In the first part, the focus was on the examination of the concept of SPS and the classification thereof. In the second part, teachers' understanding of SPS and the factors influencing their development of SPS were scrutinised. Development of SPS and biological concepts, biological literacy and biology content and an overview of the context of SPS in the Nigerian curriculum were also reviewed.

2.2 Biological Literacy and Biology Content

Biology, as the exploration of plants and animals, offers the foundational scientific knowledge essential for the advancement and growth of a nation. Additionally, it stands as a prerequisite for pursuing academic courses related to science in tertiary institutions (Akintola, 2018). Ong'amo et al. (2017) emphasised that Biology, being a scientific discipline, encompasses a multitude of concepts that have evolved through systematic experimentation and observation. To impart Biology content with effectiveness and efficiency, educators should possess a sound level of biological literacy.

Biology literacy is a component of science literacy, as defined by Mulbar and Bahri (2021). Science literacy, according to their definition, entails the capacity to employ scientific knowledge, formulate enquiries, and deduce conclusions based on evidence, enabling individuals to comprehend nature and make informed decisions about modifying the environment through human actions. Additionally, they perceive science literacy as the ability to comprehend science, convey scientific concepts, and apply scientific capabilities to resolve everyday challenges. Notably, scholars like Suryanda et al. (2017) cited in Bahtiar and Dukomalamo (2019) and Bahtiar and Dukomalamo, (2019) assert that engaging in Biology laboratory activities stimulates curiosity by facilitating discoveries grounded in firsthand experiences, utilising factual information, and constructing concepts, theories, and laws.

Mahanal et al. (2020) defined science literacy as a competency aligned with the attributes of Biology, proving highly beneficial for students. Science literacy encompasses the practice of posing enquiries about life and seeking solutions through the lens of science. In the realm of Biology, this entails continuous exploration into the intricacies of life, establishing a cohesive link between various facts in all facets of existence.

Azimi et al. (2017) submitted that scientific literacy is categorised into four classes:

- The realm of knowledge is encompassed by science.
- The exploration and study of nature through scientific enquiry.
- The cognitive approach is inherent in scientific thinking.
- The relationship between science, environment, technology, and society.

Mulbar et al. (2021) summarised the determinants of science literacy in Table 2.1

Table 2.1

Determinants of Science Literacy

Scientific Competences	Determinants of Science Literacy
Identifying scientific issues (problems)	• Discern credible scientific viewpoints (e.g., theories supporting hypotheses) • Conduct thorough literature reviews (e.g., assess source credibility and differentiate source types) • Grasp the components of research design. • Perform precise data analysis
Explaining scientific phenomena	• Create precise charts derived from pertinent data. • Tackle problems employing quantitative abilities, encompassing fundamental statistical computations (e.g., determining averages, probabilities, percentages, frequencies) • Comprehend and construe the outcomes of statistical analysis
Using scientific evidence	• Form conclusions and foresee outcomes derived from numerical data • Assess and appraise scientific information

According to Suwono et al. (2017), biological literacy can be viewed as a specific type of scientific literacy that pertains to biology. This literacy includes the ability to utilize scientific methods to comprehend and pinpoint biological problems that arise within society. This also covers the integration of these issues into the process of making informed choices, as well as the effective communication of scientific findings to others. Additionally, biological literacy involves using basic biological concepts to make educated decisions while tackling problems through scientific investigation. The education in biology equips students with vital laboratory and field competencies in biological sciences, meaningful and pertinent biological knowledge, scientific understanding for real-life applications in areas such as health and agriculture, and the nurturing of actionable scientific mindsets (FRN, 2013).

Akintola (2018) concurred that the knowledge of science is needed by all students not only science students so as to be able to cope with the anatomical, physiological, social and physical challenges of the world. For students to achieve success in Biology, it is essential that they grasp the fundamental concepts. Teachers play a crucial role in this process by providing clear and accurate explanations of these basic concepts, which, in turn, promotes the development of students' understanding and knowledge (Krauja et al., 2018).

Students' challenges with various Biology topics have prompted researchers to explore the reasons behind these difficulties. There are numerous factors contributing to students facing challenges in comprehending biological concepts (Zeidan, 2010). Çimer (2011) posits that a wide range of biological topics are perceived as complex by students. These topics include plant transportation systems, the creation of proteins, the processes of respiration and photosynthesis, the exchange of gases, concepts of energy, cellular structures, and the cellular division processes of mitosis and meiosis. Additionally, students find complexity in the study of organs, various physiological functions, the regulation by hormones, the transportation of oxygen, and various genetic concepts including Mendelian genetics, genetic modification techniques, as well as the structure and functions of the central nervous system. Nzelum (2010) also notes that a lack of comprehension of specific biological concepts and terminologies hampers the understanding of biology for some students. In order to address such challenges, this study used SPS as the basis, exploring how these skills may enable pre-service teachers to understand plant taxonomy which is a concept under biology.

Ernawati et al. (2017) and Sholikah et al. (2021) highlight the significance of biology laboratory learning as a crucial exercise that not only encourages students to establish fundamental experimental skills but also enhances their grasp of biological concepts. Educational activities that encourage open-ended, enquiry-based learning have been associated with fostering a deeper appreciation for scientific investigation (Testa et al., 2017). In exploring the implementation of the 5Es learning model specifically related to 'gases and gas laws,' Baydere et al. (2020) conducted research focusing on its impact on the conceptual understanding and development of SPS in future science educators. The outcomes revealed that this model was more successful than traditional teaching methods in correcting misconceptions concerning 'gases and gas laws' and was instrumental in improving the SPS of these pre-service science teachers.

The present study aims to explore the understanding of biology concepts among future educators, specifically concentrating on plant taxonomy. In contrast, Mulbar and Bahri (2021) conducted an investigation to assess the biology science literacy skills of Junior High School students in South Sulawesi, Indonesia, finding that the students demonstrated relatively limited scientific literacy. While Mulbar and Bahri's (2021) research delved into the biology literacy of junior high school students in Indonesia, the current study is specifically focused on pre-service teachers within a Nigerian university.

I contend that possessing SPS is crucial for biology students in comprehending biological concepts related to plant taxonomy. This importance arises because the learning process in biology inherently involves scientific procedures like observation, experimentation, and analysis. I also believe that SPS will enable students to understand biological concepts based on plant taxonomy easily and correctly.

2.3 Science Process Skills and the Nature of Science

Djamahar et al. (2019) suggest that SPS enable students to deeply understand scientific principles. Biology, which falls under the umbrella of Natural Sciences, provides insights into the lives of organisms and how they adjust to their environments. Wilson and Conyers (2020) argue that science is not merely about memorizing facts, concepts, or principles; rather, it is about embracing a scientific approach, honing a variety of skills, and applying knowledge practically. In subjects pertaining to natural sciences, SPS are aimed at both developing the abilities needed to gather knowledge and the capacity to effectively communicate findings, as outlined by Prayitno et al. (2017) and Karacop and Diken (2017).

Cigdemoglu and Köseoğlu (2019) established that teachers’ perspectives on scientific enquiry can be enhanced through the implementation of a programme focused on the essence of science and the inquiry process. On the other hand, Harahap et al. (2019) concluded that a blended learning approach is more effective than traditional teaching methods in improving student performance and cultivating SPS, specifically within the context of a plant tissue culture course.

In their study, Darmaji et al. (2019) found that a significant proportion of students demonstrated adeptness in executing practicums based on SPS. Specifically, students displayed proficiency in various facets, with percentages indicating: 48.35% for observation, 38.46% for classification, 39.56% for measurement, 58.64% for prediction, 51.65% for compiling data tables, 58.24% for making graphs, 61.54% for planning experiments, and 45.05% for conducting experiments. Additionally, the study highlighted students' capabilities in constructing hypotheses (57.14%) and defining variables (39.56%). Although the mentioned study was conducted in Indonesia among pre-service Physics students, the present study was conducted in Nigeria and focused on pre-service Biology teachers. In a comparable investigation, Juhji and Nuangchalerm (2020) illustrated 1) favourable connections between fundamentals of SPS within TPCK, 2) adverse interaction between ISPS within TPCK, 3) favourable associations between scientific attitudes towards TPCK, and 4) the existence of collective interactions. These findings may be attributed to the explicit differentiation in components between the integrated SPS variable and the TPCK component.

Science education aims to cultivate a scientific mindset in students, fostering the appropriate attitudes characteristic of proficient scientists. Hebrio (2013) defines attitude as the specific way an individual thinks, behaves, and responds. Attitudes are crucial as they have profound effects on the student, the educator, the student’s immediate social environment, and the broader educational framework. Tendencies in attitudes shape up in response to diverse experiences or through the imitation of the thoughts, actions, or stances of influential figures like parents, educators, or peers. This emulation aspect is also significant in shaping the educational dynamic, with students often absorbing and reflecting the attitudes exhibited by their teachers, which subsequently may affect the students’ academic achievements.

Education is a continual journey that encompasses both the imparting and the assimilation of knowledge. The main goal of teaching at any level of education is to effect meaningful changes within the student, which can include the development of cognitive abilities, problem-solving skills, as well as the embrace of appropriate attitudes and values. Teachers utilize various methods to assist students in acquiring knowledge alongside practical and intellectual competencies (Baysal et al., 2022). Modern educational practices underscore the importance of not just disseminating information and competencies but also molding students' attitudes, behaviors, and driving forces. Zeidan and Jayosi (2015) noted that promoting a positive disposition towards science can lead to increased student participation in SPS. Fundamentally, a deep grasp of SPS helps nurture favorable scientific attitudes, which in turn bolsters curiosity and enthusiasm. A student who is enthused about learning often develops a positive outlook on the subject matter. Therefore, educators must create a learning atmosphere that not only pulls students into the classroom but also kindles their eagerness to engage with and take pleasure in their educational experiences (Movahedzadeh, 2011).

Ediyanto et al. (2017) suggested that students with hearing impairments have the potential to excel in science process skills when instructors employ effective learning models. They proposed that the adoption of enquiry-based biology laboratory classes and augmented reality (AR) books through blended learning represents an appropriate and beneficial approach for these students.

2.3.1 Science Process Skills

Science education is crucial in instructing students to engage in enquiry, and this implies that students should possess the capability to combine skills, knowledge, and attitudes, fostering a more profound comprehension of scientific concepts (Zeidan & Jayosi, 2015). Learning science should make students critical thinkers, help students strengthen their problem-solving skills and help them develop a positive perspective about science (Mulyeni et al., 2018), hence their biological literacy. This is reasonable because scientific activities develop students' higher level of thinking (Aydoğdu, 2015) and such activities may entail SPS. Furthermore, these thinking skills (SPS) are consistently utilised most frequently (Aydoğdu et al., 2012). They are instrumental in "developing both procedural and conceptual understanding and knowledge of science since they form an important part of scientific enquiry…nature of science, and consequently promotes scientific literacy among students" (Durmaz & Mutlu, 2017, p. 433; emphases added). Opateye (2012) stressed that SPS make individuals have a positive attitude towards science. Espinosa et al. (2013) argued that SPS are highly important for science literacy.

SPS has been defined in so many ways by different scholars. Duruk et al. (2017) define SPS as skills that help in the facilitation of learning science, the development of an individual's sense of responsibility while learning and also making knowledge permanent. For Kama et al. (2018), SPS are tools that help in acquiring information about the world. Safaah et al. (2017) emphasised that SPS comprise a spectrum of abilities employed in scientific activities, and students endowed with these skills actively participate in the learning process. The application of science processes facilitates the development and integration of cognitive, affective, and psychomotor dimensions of scientific enquiry among learners, enabling them to comprehend and engage with science as an integral facet of human culture (Akani, 2015). Gultepe (2016) define SPS as the instruments that students employ to explore their surroundings and build scientific concepts. SPS are regarded as one of the methods of learning science which aids scientific investigation (Kruea-In and Thongperm, 2014; Juhji & Nuangchalem, 2020; Alatas & Fachrunisa, 2018). Based on all the definitions given by different authors above, I perceive SPS as skills that are very important for students to possess in order to be scientifically relevant in society. Possession of these skills will enable students to learn science and apply the knowledge of science to their day-to-day affairs. It will make them critical thinkers, and problem solvers and also relevant in the aspect of doing research. These SPS should not only be possessed by students but should be possessed by both scientists and teachers as well.

SPS are processing strategies that an individual uses in solving problems (Behera & Satyaprakasha, 2014). SPS helps develop the mental and physical abilities required by students to solve singular and social problems both in science and technology (Koksal & Berberoglu, 2014). Juhji (2016) argued that SPS provide a way of research to students and help them to learn and understand practical lessons. The scientific process takes place when SPS are adopted in carrying out scientific activities to generate scientific products (Prayitno et al., 2017; Wilujeng & Prasetyo, 2018). SPS encompass the abilities utilised in performing scientific tasks, generating and applying scientific information, and resolving problems (Erkol & Ugulu, 2014). They represent a refinement of skills that scientists enhance to acquire knowledge, address challenges, and draw conclusions (Karsli & Ayas, 2014). Moreover, these skills are transferable across various disciplines (Hafizan et al., 2012). Their importance for students is emphasised through their conformity with content standards, highlighting a direct approach to learning that involves the application and refinement of process skills and the cultivation of a scientific attitude, enhancing the meaningfulness of science education (Hernawati et al., 2019). Crucially, the fundamental aspect of the nature of science revolves around the methods of obtaining information and the stages of the scientific method.

The objective of science educators is to cultivate a scientifically literate society, and various resources such as textbooks, journal articles, and national organisations emphasise the pivotal role of SPS in achieving this objective (Miles, 2010). Özgelen (2012) adds that scientific literacy, a central aim of science education, requires individuals to employ scientific concepts, process skills, and values in their daily decision-making as they engage with others and their surroundings. Enhancing the scientific literacy abilities of science students necessitates the application of the SPS approach in the learning process (Kartimi & Winarso, 2021). Susanti and Anwar (2018) assert that SPS play a crucial role in fostering scientific literacy among students, underscoring the importance for science teachers to be adept in SPS to effectively impart these skills to their students. Moreover, SPS hold great significance for scientific literacy, and their absence poses a hindrance to achieving scientific literacy, as it entails more than just reading and hearing – it demands the effective utilisation of SPS (Ewers, 2001 as cited in Aydoğdu, 2015). Suryanti et al. (2018) conducted research employing a process skills method to improve the scientific literacy of elementary students. The study, conducted in two cycles involving planning, execution, observation, and contemplation phases, exhibited an improvement in students' science literacy skills when using the process skills approach in education.

SPS stands out as a fundamental skill in scientific enquiry, playing a crucial role in the execution of scientific activities. According to science educators, scientific enquiry serves as a facilitator for both conceptual knowledge and the acquisition of SPS (Minstrell & Van Zee, 2000). This process contributes to the enhancement of teachers' and students' SPS, encompassing activities like data gathering, information organisation, interpretation, and effective communication of conclusions (Metz, 2000 as cited in Mbewe et al., 2010). Scientific enquiry goes beyond SPS, integrating it with other elements such as scientific reasoning, scientific knowledge, and critical thinking (Mulyeni et al., 2019). Gaining SPS lays the groundwork for engaging in scientific enquiry and developing the cognitive abilities essential for understanding biological concepts (Nwagbo & Chukelu, 2011). According to Inayah et al. (2020), proficiency in SPS is a fundamental requirement for students involved in scientific activities. The efficacy of enquiry-based learning in improving students' science process skills has been substantiated (Kunga, 2021). Enquiry is viewed as a strategic approach to skill development, providing students with opportunities to acquire new information through various skills. Enquiry enables learners to develop the skills required during their lives (Duran & Dökme, 2016).

2.3.1.1 Classification of Science Process Skills

Irwanto and Prodjosantoso (2018) have formulated SPS to encompass both BSPS and ISPS. Jack (2013) has suggested that BSPS and ISPS are interrelated and align with the science subjects taught at the secondary school level. BSPS involves activities such as observation, classification, prediction, measurement, summarization, and communication, as identified by Zeidan and Jayosi (2015) and Handayani et al.

(2018). On the other hand, ISPS includes tasks such as identifying variables, formulating hypotheses, tabulating and graphically representing data, defining variables, designing investigations, and conducting experiments, as elucidated by Ongowo and Indoshi (2013).

BSPS form the foundation for the acquisition of ISPS and they are more of thinking skills (Susanti and Anwar, 2018). Santos and David (2017) added that fundamental SPS (BSPS), including observation, numerical application, and classification, serve as the basis for gaining integrated SPS (ISPS). For Akinbobola and Afolabi (2010), BSPS are regarded as crucial to elementary school science education as well, and they are regularly joined with science content, permitting youngsters to learn both science processes and content at the same time. They further emphasised that these skills are crucial for science education and the development of concepts, especially at the primary and junior secondary school levels. ISPS are problem solving skills or skills used for doing science experiments (Idiege et al., 2017). They are skills students need to design and conduct scientific investigations. They are used in tandem with BSPS at senior secondary school level of education. They (ISPS) demand more critical thinking from students. Both ISPS and BSPS are also used in tertiary institutions for science courses such as chemistry, physics, biology, integrated science, computer science, and so on. Students must master and also develop these skills. Some of the BSPS and ISPS are explained in Table 2.2.

Table 2.2

Types of Basic Science Process Skills and Integrated Science Process Skills.

Classification	Types	Explanation
BSPS	Observing	Entails gathering information about the world through the use of the senses. It serves as the initial stage in gathering information and is the sole method for acquiring knowledge about the world (Charlesworth & Lind, 2010).
	Measuring	Utilising established measures or approximations to articulate particular dimensions of an object or occurrence (Ediyanto et al., 2017).
	Interpreting	Offering a quantitative explanation for a specific object or substance is the essence of interpretation (Inayah et al., 2020)
	Classifying	The process of grouping objects or events into categories based on characteristics. For example, objects can be sorted based on colour, size, or shape (Charlesworth & Lind, 2010).
	Predicting	Predicting future occurrences by extrapolating from past observations or data extensions (Inayah et al., 2020).
	Communicating	Utilising language, symbols, or visuals to depict an object, action, or event (Inayah et al., 2020).
ISPS	Identifying and Controlling Variables	Having the capacity to recognise variables that may influence the result of an experiment, maintaining most factors constant while altering only the independent variable.
	Formulating Hypothesis	Expressing the anticipated solutions or predicted results for experiments (Ediyanto et al., 2017).

Experimenting	Conducting experiments involves manipulating and controlling independent variables to test hypotheses and observing their impact on the dependent variable. Following experimentation, the findings are analysed and communicated in reports, providing a framework for others to reproduce the experiment (Inayah et al., 2020). Performing an experiment entails meticulously adhering to the procedural instructions, allowing the results to be confirmed through repetition of the procedure multiple times (Zeidan & Jayosi, 2015).
Interpreting Data	Analysing data involves drawing explanations, conclusions, or hypotheses based on data that has been graphed or organized in tables (Inayah et al., 2020).
Operational Definition	Expressing the method of measuring a variable in an experiment (Ediyanto et al., 2017).

To conduct the study, I employed both BSPS (observation, classification, prediction, measurement, and communication) and ISPS (formulating hypotheses, identifying and controlling variables, operational definition, data interpretation, and experimentation). The choice of these skills was informed by research conducted by various authors within the Nigerian context (Mirian, 2023; Ugwuanyi & Nwafor, 2021; Idiege et al., 2017). Mirian (2023) carried out a study on the assessment of SPS among science students in a Nigerian school. She selected specific SPS from both basic and integrated SPS. The study revealed that while most students performed very well in BSPS, the struggled in ISPS. Idiege et al. (2017) provided an in-depth analysis of various SPS within the Nigerian curriculum, some of which are incorporated into this study. Additionally, Erkol and Ugulu (2014), in their study conducted in Turkey, investigated the levels of SPS among biology teacher candidates and compared these levels based on various variables. The study comprised 121 aspiring biology teachers, evaluating their proficiency in integrated SPS (ISPS), which encompassed tasks like variable identification and control, hypothesis formulation, data analysis, graph drawing, and experimentation. The results underscored a requirement for the improvement of SPS in biology PST.

In a similar study carried out by Gezer (2015) in Turkey, the self-efficacy in laboratory usage and the scientific process skills (SPS) of 66 future biology educators were examined. The research emphasized a range of integrated (ISPS), which comprised defining variables, operational explanations, hypothesis development, graphical representation and data interpretation, as well as research design. The results indicated noteworthy associations across all aspects of the SPS assessment.

In their research, Kruea-In et al (2015) investigated the grasp of SPS among science teachers in Thailand. The study included participation from both practicing (n=125) and aspiring (n=55) educators within the field of science education. Assessment focused on fundamental skills such as observation, inference, classification, measurement utilization of numerical data; communication; prediction; and comprehension regarding spatial-temporal relationships (BSPS).

Kamba et al. (2018) examined the connection between students' attitudes toward physics and their proficiency in scientific process skills within senior secondary schools in the Aliero metropolis, Nigeria. The research involved 203 students from three secondary schools and evaluated both BSPS and ISPS, which encompassed activities such as observation, measurement, classification, prediction, communication, controlling variables, hypothesis formulation, experimentation, and data interpretation. The results indicated a deficiency in students' knowledge of SPS, positive attitudes towards physics, and a noteworthy positive correlation between students' SPS proficiency and their favourable attitudes toward physics.

Chabalengula et al. (2012) undertook research at a Midwest university in the USA, concentrating on the conceptual grasp and proficiency of SPS among PST. The study involved 91 elementary pre-service teachers, evaluating both BSPS and ISPS. The findings indicated that PST demonstrated a constrained grasp of concepts of SPS.

In a distinct research endeavour, Guevara (2015) explored the consequences of integrating inventive pedagogical strategies in a general biology course on the enhancement of SPS. The investigation encompassed two intact classes comprising non-science freshmen at a government-managed higher learning institution in the Philippines. The evaluation of ISPS, involving activities such as data gathering, experiment design, experimentation, problem-solving, model construction, and conclusion drawing, revealed notably higher SPS scores among students who experienced the combined methodology of multiple representations and collaborative learning.

Obialor et al. (2017) explored how students' project work affected the development of SPS in Biology among secondary school students. The study, conducted in Owerri North Local Government Area of Imo State, Nigeria, involved a group of 134 SSII biology students. The findings demonstrated a significant and positive influence of students' project work on the improvement of both BSPS and ISPS in the realm of biology. These skills revolved around activities such as observation, classification, measurement, data interpretation, hypothesis formulation, and experimentation within the field of biology.

I observed that most of the research above was conducted outside the Nigerian context and the ones carried out in Nigeria were conducted on secondary school students. Also, none of the studies above focused on plant taxonomy as a biological concept but the present study hinged on plant taxonomy. This served as an incentive for this research to fill up the existing important research gaps identified in the literature above.

2.4 Teachers' understanding of science process skills

Over the years, numerous studies have examined the significance of teachers' comprehension of SPS. Despite the ample body of research underscoring the importance of SPS for educators, there is empirical evidence suggesting that teachers lack adequate knowledge and understanding of these skills. An investigation conducted by Karsli and Şahin (2009), which explored teachers' perceptions of SPS through open-ended questioning, revealed a substantial deficiency in their understanding, particularly in theoretical aspects. Those who exhibited a lack of comprehension often cited constraints such as time or resource limitations. This aligns with other research findings indicating that a considerable number of science and technology, preschool, and pre-service teachers are either unaware of or proficient in fostering SPS development. Additionally, in-class activities frequently fall short of ensuring that students acquire these essential skills (Mbewe et al., 2010; Turkmen & Kandemir, 2011). For instance, Hernawati et al. (2019) argued strongly that teachers must harbour a positive attitude towards science to capture students' interest in engaging with the scientific process.

Based on several studies carried out by different authors (Aydin Ceran & Esen, 2022; Reymund, 2019; Widdina et al., 2018; Akinbobola & Afolabi, 2010) on why students still possess low levels of SPS, many factors are said to be responsible one of which is science teacher's ability and understanding of SPS. In agreement with this, Sukarno et al. (2013) conducted a study on the comprehension of science teachers regarding science process skills (SPS) and its implications for science learning in junior high school. The findings indicated a notable lack of understanding of SPS among science teachers, potentially impacting their effectiveness in teaching science and fostering science process skills development in students. The teaching methodologies employed in science classrooms present an opportunity to instil SPS, underscoring the importance of teachers recognising these skills as crucial for science learning. SPS serves as a scaffold for other cognitive skills like logical thinking, reasoning, and problem-solving. To effectively integrate SPS into the learning process, clear instructions are essential, ensuring that students are cognisant of the specific SPS targeted and are guided through exploratory questioning (Maranan, 2017).

Yilmaz and Granena (2019) discovered a favourable connection between students' ability to hypothesise and their science process skills (SPS). This suggests that educators should employ creative instructional models in the classroom to enhance students' SPS. In a study by Gürses et al. (2015) focusing on 10th and 11th-grade students, a significant difference in BSPS was noted between the two groups. The distinction may arise from 11th-grade students emphasising knowledge-based problem-solving in preparation for university entrance examinations, potentially limiting their engagement with SPS. Various factors, including instructional methods, teachers' content knowledge, and school efficiency, can contribute to these differences. Aydoğdu (2015) highlighted variations in science teachers' SPS usage frequency and in-service training, emphasising the importance of teachers possessing a solid understanding of SPS to effectively impart these skills to students. Teachers play a crucial role in assessing students' SPS, ensuring that their mastery of these skills is adequately evaluated. Employing effective instructional materials is one-way teachers can assist students in developing their SPS (Gürses et al., 2015).

Widdina et al. (2018) reported in a study carried out on the profile of students' SPS that the ability of students' SPS is relatively still low and this happened due to various reasons: a lack of human resources of science teachers in teaching students SPS and a lack of science materials and tools in supporting teachers in teaching the students to improve and develop SPS. In a study conducted by Hikmah et al. (2018), the findings revealed that teachers tailor their teaching methods based on their individual comprehension of science process skills (SPS). Specifically, teachers who perceive SPS as involving the application of scientific methods utilise practical work and science projects to impart these skills to students. On the other hand, those who view SPS as students' ability to employ reasoning and creativity in understanding science prefer employing problem-based learning models and discussion methods to teach SPS. In a study involving pre-service science teachers, Yıldırım (2016) observed that some teachers lacked sufficient knowledge of SPS in the field of science education, while some individuals voiced no viewpoints regarding the issue.

Hacieminoglu's (2016) investigation revealed that students generally exhibited a low positive attitude towards science, potentially influenced by teachers' diverse implementations of the science and technology curriculum and variations in the classroom environment. In research conducted by Wendell and Rogers (2013), the implementation of an engineering design-centered science curriculum was associated with marked advancements in science subject matter among elementary students. Notably, these advancements exceeded those witnessed when the same educators employed their school or district's typical science curricula. Maranan (2017) categorised students into the mastered level, low mastery and no mastery level and suggested that the third category of students must be assisted to improve their SPS and performance. Additionally, it was recommended that science teachers can enhance student performance by employing science-boosting and student-centred strategies. Emphasising basic science process skills (BSPS) and implementing collaborative group activities were highlighted as effective approaches.

Lin Ting (2014) pointed out that one of the prominent means of enhancing observational skills of students is by taking learning and instruction beyond the walls of a classroom, providing opportunities for students to engage all senses through seeing, touching, feeling, smelling, and hearing. This perspective aligns with Sugiyono's (2017) study, affirming the potency of outdoor learning methods in enhancing the quality of science education. Research by Amran (2017) indicated that utilising KIT IPA in learning leads to increased student engagement and direct application of acquired concepts, resulting in improved learning outcomes. Yadav and Mishra (2013) emphasised the benefits of a laboratory approach, specifically through experimental activities, in fostering students' science process skills (SPS). Wagino et al. (2022) research further supported this idea, demonstrating that the use of experimental methods positively impacted science learning achievements among fourth-grade students. Therefore, the improvement of students' SPS in science learning can be effectively accomplished through hands-on experiments.

Aydin Ceran and Esen (2022) highlighted findings from their study on the SPS of fourth-grade primary school students, indicating that their SPS levels, particularly in observing, designing experiments, and interpreting data, are categorised as low. This may be attributed to the infrequent incorporation of experimental activities in science learning. The expectation in science education is for students to develop critical thinking skills through experiments related to daily life. Rini (2017) also noted a low level of SPS in experimental skills in their study, while Raj and Devi (2014) found a very low positive correlation (0.230) between SPS and science achievement among high school students. Lindrawati and Rohandi (2015) emphasised the importance of pre-service physics teachers possessing SPS, asserting that effective teachers should have a suitable understanding of SPS and be able to apply it in classroom activities as needed. The study raises the question of whether pre-service biology teachers in Nigerian universities possess these essential skills, with the findings expected to provide insights into this matter.

2.5 Development of science process skills and biological concepts in pre-service teachers

SPS help to promote scientific literacy among students. As referred to elsewhere, biological literacy is embedded in scientific literacy (Krauja et al., 2018). Thus, it is reasonable that science teachers themselves have the experience, knowledge and understanding to teach these skills (Chabalengula et al., 2012) to be able to impart biological concepts better. The cultivation of science process skills (SPS) within educational settings encompasses a range of abilities that students in science must demonstrate, aiming to instil a more tangible and meaningful learning experience. Teachers play a crucial role in nurturing students by emphasising not only foundational knowledge like skills, facts, concepts, theories, and laws but also by fostering scientific enquiry through activities such as investigations, as suggested by Idiege et al. (2017). Ugwuanyi (2015) argue that SPS can be developed through training that is embedded in science practical activities. How do pre-service teachers use SPS to understand biological concepts based on plant taxonomy? This is the objective of this study.

In a study by Chabalengula et al. (2010), they investigated the familiarity, interest, and conceptual understanding of SPS among PST. The results indicated a general deficiency in the ability of pre-service teachers to develop SPS. In a related study by Erkol and Ugulu (2014) examining the SPS levels of biology teacher candidates, the results indicated a need for the enhancement of SPS levels among pre-service biology teachers. Gultepe (2016) investigated high school science teachers' perspectives on SPS, revealing that teachers often lagged behind in SPS development. Susanti and Anwar. (2018) emphasised the significance of pre-service teachers' SPS development, noting its role in enhancing learning abilities and supporting critical thinking skills. The current study aimed to explore how PST developed SPS to comprehend biological concepts, specifically focusing on plant taxonomy.

Fugarasti et al. (2019) suggested that the assessment of SPS ought to be done to develop students' skills. Widyaningsih et al. (2020) emphasised the significance of SPS in the learning process, noting that these skills play a crucial role in fostering students' ability to formulate thoughts and make discoveries. The development of SPS enables students to actively acquire and generate new knowledge. It is advocated that the content taught in science classrooms should be leveraged to cultivate SPS (Nyakiti et al., 2010). Highlighting the central role of SPS, Harlen (2010) suggests that their development should be a primary objective in science education. Adedoyin and Bello (2018) investigated the conceptions of the Nature of Science among undergraduate pre-service biology teachers in South-West Nigeria. The study revealed that these teachers held more misconceptions than correct conceptions, possibly attributed to insufficient knowledge about the nature of science. Aydoğdu (2015) adds that studies have shown that teachers with well-developed SPS can easily teach these skills in the classroom, hence developing their learners.

Yıldırım et al. (2016) remarked that the most effective technique for the development of process skills in science is enquiry-based learning. According to Opulencia (2011), fostering fundamental process skills is integral to cultivating a sound scientific attitude and values. Science education is oriented towards training students to adopt a scientific mindset, emphasising the importance of developing attitudes which are characteristics of proficient scientists (Opulencia, 2011). Teaching serves the purpose of instilling positive attitudes and values (Baysal et al., 2022). The development of SPS enables students to prepare for the challenges they will face by changing their behaviours and getting the motivation necessary for today's world (Miller, 2017). Erkol and Ugulu (2014) contended that nurturing students' science process skills (SPS) holds significant importance in education as it enhances learning abilities and fosters critical thinking skills. In addition to SPS, the teaching of biological concepts presents challenges for educators, as reported by Chavan (2016). The teachers faced difficulties in understanding some biological concepts like cell, sporogenesis, segmentation, and so on. Many teachers face difficulties in the classroom while teaching biology concepts due to some biological concepts being abstract, making it difficult for them (teachers) to comprehend (Chavan, 2016) and, thus, will not be able to appropriately teach such concepts to the students.

Chavan and Patankar (2018) investigated the understanding of biological concepts among higher secondary teachers and found that a majority of them lacked awareness of these concepts. They struggled to differentiate between biology facts, terms, attributes, and concepts present in the textbook content. Various studies have explored different aspects of biological concepts. Tahir (2017) researched the SPS of biology PST when solving problems related to plant physiology. The findings indicated that the teachers exhibited low SPS, particularly in their ability to interpret data. In a study by Widdina et al. (2018) focusing on students' SPS in learning about human muscle tissue experiments at the secondary school level, the students' BSPS were categorised as sufficient.

Teachers' improvement of SPS contributes to fostering SPS in students. Hernawati et al. (2018) investigated the impact of integrating project activities to enhance SPS and self-efficacy in the teaching of Zoology of Vertebrates. The results demonstrated a significant influence of including project activities on the SPS and self-efficacy of PST, displaying statistical significance at the 0.05 level. This indicates that integrating project activities into the educational process has the potential to effectively bolster SPS skills and self-efficacy in aspiring biology educators. The findings provide valuable insights for biology teacher candidates and educators, underscoring the advantages of incorporating projects that encompass a variety of skills for the training and cultivation of SPS and self-efficacy. This study, while similar to the current one, differs in that it was conducted outside of the Nigerian context and focused on different biology concepts.

Malikah et al. (2016) pointed out that traditional modes of learning fail to engage students and result in unsatisfactory outcomes, contributing to students' lack of interest in the subject matter. This perspective aligns with Turkmen and Unver's (2018) that shifts in the learning environment can be achieved through student-centred learning, particularly in enhancing science process skills (SPS). Conventional learning methods often fall short of cultivating students' critical thinking and hypothesising abilities, preventing them from actively constructing their knowledge. Herrmann (2013) investigated cooperative learning models and found that they promote students' active participation and foster mutual respect among peers. He concluded that such models offer an alternative for teachers aiming to implement student-centred learning. Additionally, classroom observations indicate a prevalent use of textbooks in teaching science, with limited emphasis on encouraging students to explore information independently. Moreover, the content of these textbooks may not sufficiently address the materials required for developing the experimental skills of science students, potentially hindering their skill development, particularly in experimentation. In light of the above, I believe that teacher needs to challenge students to think critically by providing the necessary skills during learning.

Many pieces of research have been carried out on pre-service teachers' SPS and different biological concepts as seen in some of the works of literature above, but, arguably, there is still limited study carried out on SPS within the plant taxonomy contexts in which this study intended to fill the research gap.

2.6 Overview of the Context of Science Process Skills in the Nigerian Curriculum

The educational system in Nigeria is structured into Primary, Secondary, and Tertiary levels (Aina & Langenhoven, 2015). This study primarily focused on the tertiary level, where science education encompasses biology, chemistry, and physics, along with the principles and methods of education. The Nigerian government, like its counterparts worldwide, recognises the significance of science education, as evidenced by its promotion outlined in the NPE. According to Ajibola (2008), the NPE serves as a guide for the development of the science education curriculum. Science education can be conceptualised as a teaching process within the school system aimed at enhancing knowledge about the environment and fostering systematic inquiry skills (Badmus & Omosewo, 2018).

The goal of science education by FRN (2004), as stated in the NPE is to:

Promote inquisitive, knowledgeable, and logical minds to promote liberty and a happy life; foster the growth of scientists for the country; research on technology service and the factors that lead to technological advancement; provide information and comprehension about the forms, behaviours, and difficulty of the physical environment (FRN, 2004, p. 29).

Akpan (2008) underscored the pivotal role of science education in moulding individual lives and contributing to a nation's scientific and technological progress. To align science education with the objective of enhancing Scientific Process Skills (SPS) for addressing scientific challenges and promoting national development, Nigeria conducted workshops that led to the overhaul of subject curricula at various educational levels. Organisations of science teachers in Nigeria have actively partaken in shaping curriculum development, significantly emphasizing the acquisition of SPS. The Nigeria Educational Research Council (NERC) and the Comparative Education Study and Adaptation Centre (CESAC) have played a pivotal role in influencing the evolution of science curricula in Nigeria. Aligned with the government's commitment to advancing science education, teacher vacation courses have been organized, specifically focusing on integrated science, biology, chemistry, and physics, in line with the updated curricula, yielding positive outcomes (Ojebiyi & Sunday, 2014).

The various curricula developed by SAN, STAN, NPSP, NSSP, and NISP outline specific objectives aimed at achieving Science Process Skills (SPS), understanding science, and fulfilling national goals (Obialor et al., 2017). According to Mbewe et al. (2010), the primary objective of science education is the acquisition of SPS, given its universal applicability to all citizens, not just scientists. Akinbobola and Afolabi (2010) asserted that SPS enable students to develop qualities such as creativity, reflective problem-solving, innovation, and inventiveness—qualities essential for national development in the field of science and technology. Reports from WAEC Chief Examiners (2012, 2013, and 2014) highlighted unsatisfactory responses from candidates in science subjects, suggesting a lack of acquired skills possibly stemming from insufficient exposure to laboratory devices. This underscored the need for investigation and prompt intervention in science education. The fulfilment of objectives outlined in the NPE is crucial for enabling students to acquire SPS, foster positive attitudes towards science, and contribute to the nation's central goals.

2.7 Means and Methods of Teaching Science Process Skills in Science Education

The difficulties facing Nigerian science education have long been recognised. In this vein, Omosewo (2009) noted that a considerable proportion of educators designated to instruct science courses in Nigerian schools were proficient in the subject matter but had no experience teaching science. He further noted their deficiency in appropriate instructional strategies, often relying on the lecture method. Miles (2015) underscores the expectation for teachers to employ diverse instructional approaches to ensure academic success for all science learners. He advocates for science educators to incorporate methodologies that actively engage learners in various activities. Al-Rawi (2013) contends that the lecture method is a suboptimal teaching approach, focusing more on information delivery than on student engagement. Nguyen, Williams, and Nguyen (2012) assert that social interaction between learners and teachers is pivotal in the learning process, emphasising the importance of teaching methods that foster maximum social interaction in the contemporary educational landscape. Based on the argument above, I believe that the type of teaching strategy a teacher uses determines the outcome of learning for the students. Teachers need to be creative with their teaching strategies and also engage their students in collaborative learning.

Eminent researchers and authorities in science education, including Omoifo (2012), Egbunonu and Ugbaja (2012), and Bichi (2012), have advocated for the adoption of diverse, research-driven, learner-centric teaching strategies and methods in science instruction. These strategies encompass enquiry-based approaches, cooperative learning methods, and the utilisation of problem-solving teaching techniques. Despite these recommendations, classroom observations in Nigerian secondary schools, as reported by Owolabi (2012), indicate a prevalent reliance on highly expository and teacher-centred science classroom activities. The persistent preference for teacher-centred approaches among science teachers is attributed to several factors, including inadequate physical infrastructure, a shortage of laboratories and equipment, insufficient science textbooks, and a science curriculum lacking in directive for enquiry (Omoifo, 2012). Furthermore, the problem is worsened by a lack of adequate professional growth, specifically the absence of instruction for science educators in critical domains like adaptation, handling extensive classes, and teaching complex ideas (Owolabi, 2012).

The old-fashioned teaching methods approved by science educators are evidently failing to yield results as students continue to underperform in science disciplines (WAEC 2008, 2010, 2014; Omoifo, 2012). Erinosho (2013) noted a deterioration in students' academic achievements in science subjects. Several researchers (Wanbugu et al., 2013; Oladejo et al., 2011) identified teachers’ teaching methods as the cause of low academic performance. Nwosu (2010) noted that many active science educators lack the ability to proficiently instruct science disciplines, notably chemistry, in secondary schools. This insufficiency has adversely affected the nurturing of SPS. Within this research, the failure of pre-service teachers to develop SPS posed a significant issue, as the lack of SPS development in pre-service teachers would hinder their ability to apply these skills in comprehending biological concepts related to plant taxonomy.

Ugwuanyi (2015) stated that the application of SPS is an essential pointer to knowledge transfer which is required for problem-solving in practical activities. The knowledge and understanding of SPS are significant for proper understanding of science concepts, such as those related to biology. As per Adebusuyi et al. (2023), the practical abilities in chemistry should integrate Science Process Skills (SPS), essential elements within the chemistry curriculum, encompassing both cognitive and psychomotor competencies employed in addressing problems. Dogan and Kunt (2016), as well as Suyidno et al. (2018), noted in their discoveries that a deficiency in SPS would impede the learning process in higher education. Alkan (2016) put forth that learning engages a scientific process and pre-service educators need to be armed with SPS competencies to enhance their effectiveness.

From the literature reviewed above, I observed that the majority of science educators both at secondary school and post-secondary school still adopt traditional and lecture methods. The present study focused on the PSTs' use of SPS in understanding biological concepts based on plant taxonomy in order to fill the research gap.

2.8 Factors Influencing the Development of Science Process Skills

As referred to earlier, rhetoric debates around biological literacy are not new (Klymkowsky, 2005; Wright, 2005). Wright's (2005) views, in particular, may be used to argue for the importance of the development of science process skills in biological literacy:

Proficiency in a subject goes beyond memorising specific facts; it involves the skill to access, assess, and apply information from various sources in a way that demonstrates expertise in that field. It extends beyond mere content retention, aiming for students to establish meaningful connections between the subject matter and their lives. The ultimate goal is to equip students with the ability to critically evaluate information in subsequent encounters, reshape their worldview, and cultivate a heightened interest in the subject, particularly in biology (Wright, 2005, p. 191; emphasis added).

In my opinion, SPS are key to making connections between biological concepts and our everyday life. Furthermore, PST may not be able to tap into their critical thinking skills without the use of SPS as a foundation. SPS are instrumental in scientific and biology literacies. Thus, there is a need to illuminate factors that influence their (SPS) development in teacher education.

Obialor (2016) asserts that despite the extensive efforts by the government, various agencies, and professional bodies to emphasise the importance of students mastering science process skills (SPS), there remains a significant gap in the acquisition of these proficiencies. Consequently, students may graduate from secondary schools without attaining an adequate level of SPS. The mastery of these skills is important because of the role they play in a nation's development and solution to scientific problems. He goes further to maintain that teaching methods do not influence the acquisition of SPS desirable for a suitable understanding of biological concepts. Obialor (2016) suggests that other factors influence pre-service teachers' acquisition of SPS needed for an appropriate understanding of biological concepts. For Ikeobi (2010), teachers are a key factor in the acquisition of SPS in science subjects.

In the same vein, Orlich et al. (2010) opined that all instructors must possess ethics and moral obligation to support all students to recognise their full potential. Alkan's (2016) subsequent argument suggests that learning entails a scientific process and teachers must be furnished with the SPS to develop the quality of teaching. Miles (2010) observed that teachers with adequate SPS are able to teach effectively and their learners perform excellently. I believe that when teachers possess SPS, it will be easy for them to relate these skills to their students. In relation to this study, when pre-service teachers can adequately use these SPS to understand biological concepts, it will enable them to really acquire these skills and be able to teach these skills to their students when they become in-service teachers or during their teaching practice.

Al-Rabaani (2014) carried out research on the acquisition of SPS by pre-service social studies teachers in Oman. The findings revealed no notable difference in SPS acquisition between genders. This lack of distinction is attributed to both male and female teachers participating in courses within the same learning environment. Saracoglu et al. (2012) reported that parents' level of education played a significant role in the development of students' SPS. This might be because educated parents attach more importance to education. They conveyed that there was no notable distinction between genders concerning the students' SPS. Additionally, Karar and Yenice (2012) appended that the occupations of parents play a crucial role in the advancement of students' SPS.

Opara (2011) found that enquiry-based teaching approaches facilitated students' achievement in science subjects. Dewi (2014) cited in Widyaningsih (2020) claimed that 45.45% of students scored below the KKM in SPS, with an average score falling in the low category. Dewi (2014) added that the inadequate development of SPS in students can be attributed to an insufficiently innovative learning system in the laboratory. These results were strengthened by Rini (2017) who reported that the low level of SPS specifically in practical activities was caused by the factors below:

- Infrequent incorporation of experimental activities into the learning process;
- Inadequate utilisation of innovative learning models to enhance experimental activities;
- Suboptimal utilisation of learning media and teaching aids to support experimental activities;
- A significant number of students engage in passive learning participation.
- Suboptimal quality of learning and less-than-optimal academic outcomes attained by students.

From the analysed data, it can be deduced that various factors contribute to the limited development of experimental skills. The scarce use of the experimental approach in science education and inadequate utilization of visual and instructional resources are noted as considerable contributing factors. Obialor (2016) emphasised the persistent issue of non-acquisition of SPS, pointing out that students might complete their secondary education without adequately mastering these skills. This occurs despite substantial efforts by governmental bodies, agencies, and professional organisations to emphasise the importance of students acquiring SPS, recognising their pivotal role in national development and addressing scientific challenges.

Obialor (2016) asserted that the teaching approach does not impact the acquisition of SPS necessary for a comprehensive understanding of biological concepts. The focus of this study was to explore whether the teaching method influences the acquisition of SPS among PST, essential for a thorough grasp of biological concepts. Sampson and Yeoman (2010) emphasised the teacher's role in providing structure, support, and professional guidance to students in the analysis, interpretation, and reporting of findings. Similarly, Turkmen and Kandemir (2011) discovered that the SPS proficiency of teachers was insufficient.

It can be argued, based on the above-reviewed literature, that there are few studies (Obialor, 2016; Ikeobi, 2010, Saracoglu et al., 2012) on factors influencing the SPS development of students. For this reason, the presented study explored the factors influencing the SPS development of PST. I also observed that, arguably, no comprehensive research had been conducted in Nigeria on the factors influencing the development of SPS of students, specifically PST. It was on this premise that this study critically explored the factors influencing the SPS development of PST.

2.9 Chapter Summary

The chapter explored the issue of SPS development among PST, focusing on the Nigerian educational context. Despite the acknowledged importance of SPS in science education, studies revealed a notable gap in teachers' understanding and application of these skills. Teachers often lack theoretical comprehension of SPS, citing constraints such as time and resource limitations.

The chapter underscored the vital role of teachers in fostering SPS development. Teaching methodologies in science classrooms were identified as crucial opportunities to instil SPS, emphasising the need for teachers to recognise these skills as fundamental for science learning. The correlation between students' ability to hypothesise and their SPS underlines the significance of creative instructional models in enhancing SPS in the classroom.

Several factors contribute to the limited development of SPS, including variations in teachers' content knowledge, school efficiency, and instructional methods. The study also highlights the importance of teachers possessing a solid understanding of SPS to effectively impart these skills to students. Effective instructional materials and hands-on experiments are key strategies for assisting students in developing their SPS.

Examining the Nigerian educational system, the chapter noted the structure into primary, secondary, and tertiary levels. The National Policy on Education (NPE) guides the science education curriculum, but challenges persist, such as inadequate infrastructure, shortages of laboratories and equipment, insufficient textbooks, and deficiencies in teachers' instructional strategies.

The literature also explored the development of SPS in the context of biological concepts among PST. The goal is to promote scientific literacy, recognising that science teachers need experience, knowledge, and understanding to teach these skills. The study aimed to address the research gap by examining how pre-service teachers use SPS to understand biological concepts based on plant taxonomy.

Factors influencing the development of SPS are diverse, including the role of teachers, gender, parental education, occupation, and the quality of the learning system. Despite governmental efforts, a significant gap remains in the acquisition of SPS, emphasising the need for further research in the Nigerian context.

The chapter provided a comprehensive overview of challenges and opportunities in SPS development among pre-service teachers, particularly in Nigeria. It highlighted the need for further research to address identified gaps and offered insights into the complex factors influencing the acquisition of SPS.

Chapter Three: Theoretical Framework

3.1 Introduction

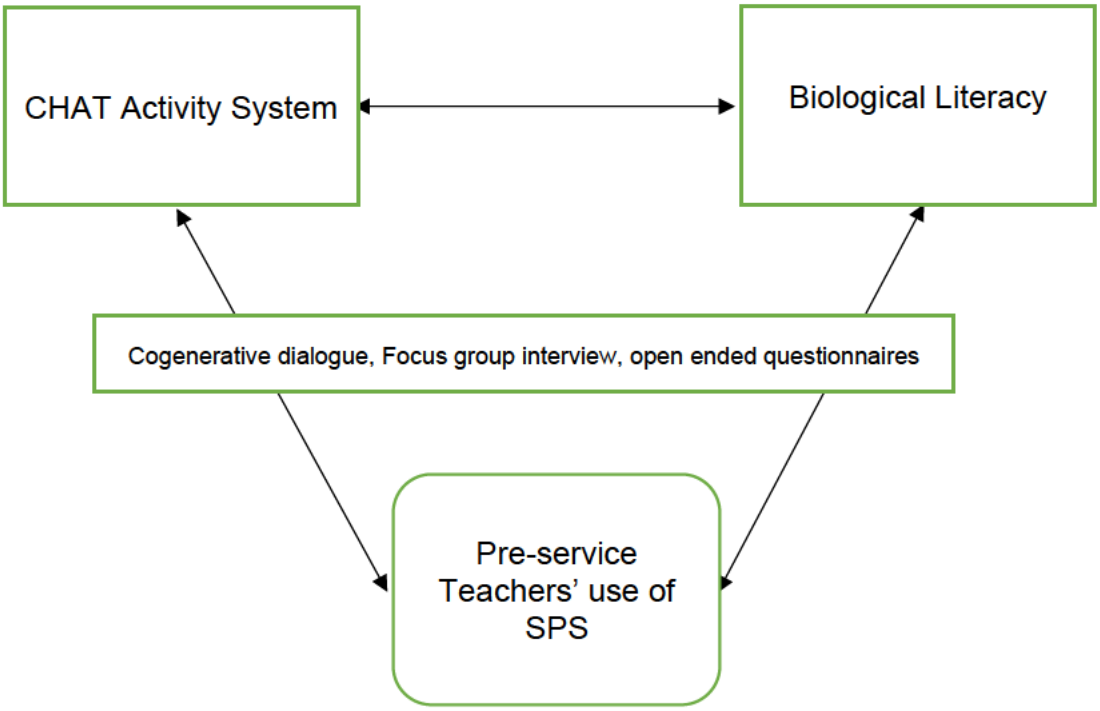
The background needed to undertake this study was provided in the previous chapters and in this section, I lay up the theoretical basis for this research. Grant and Osanloo (2014), opined that the development of a theoretical foundation is one of the pivotal steps in the research process. In addition, Ravitch and Carl (2019) agreed that researchers can use the theoretical basis as a guide to help them apply formal theories to their findings. For this reason, it influences the researcher's decision making about research design and data analysis strategy (Abutabenjeh & Jaradat, 2018). They emphasized that the theoretical foundation guides every facet of the research process, including delineating the problem, conducting the literature review, determining the methodology, presenting and discussing results, and drawing research conclusions.

For this study to be clear, it was important to guide the study with a theoretical framework, as noted by Grant and Osanloo (2014), a study's goal is unknown in the absence of a theoretical basis and it makes the project findings more meaningful and generalisable (Akintoye, 2015). As previously mentioned in Chapter 1, this study explored how pre-service biology teachers use SPS in understanding biological concepts based on plant taxonomy. It should be noted that these pre-service teachers (PST) were in their third and fourth year respectively and they all had varying degrees of prior knowledge and misconceptions of SPS.

This study is based on the assumption, supported by Nursalam et al. (2022), that these PST, through their interactions with lecturers, the school environment, and peers, should be able to develop and refine their use of SPS to understand biological concepts. Similarly, this assumption is grounded in Vygotsk's (1978) theories on social learning, which propose that cognitive development is heavily influenced by social interaction and cultural tools, suggesting that learning occurs through collaborative activities and guided participation. This perspective aligns with the principles of CHAT framework, where the social context and collective learning play important roles in the development of SPS (Matta, 2023). To explore this, I employed the CHAT activity system and Biological Literacy as the theoretical framework. These frameworks help in analysising the PST's use of SPS not just as a cognitive process of an individual, but also a process embedded in social and cultural contexts. Thus, the present research contributes to the literature by proposing a new way of incorporating SPS frameworks to explain how SPS can be used to understand plant taxonomy. These two frameworks when combined give a new approach to the use of SPS for understanding biological concepts as shown in Figure 2.

Figure 2.1

Theoretical Frameworks and the Phenomenon being Explored



3.2 The Cultural-Historical Activity Theory (CHAT)

Vygotsky (1978) is credited with giving rise to CHAT and as scholars understood the significance of social facets of learning, they have used CHAT more frequently in educational research. In relation to this study, when the PST are learning by interacting with the artefacts in their environment, they are able to develop skills like SPS critical thinking skills which they can use to understand plant taxonomy. CHAT has evolved through three generations of research, namely the first, second, and third generations (Olavarría, 2013).

The first version of CHAT was developed by Vygotsky, also known as the concept of mediated action. This has to do with the fact that humans do not interact directly with their environment but are interceded through the use of objects (Fleer, 2009). Vygotsky (1978) argued that human beings are agents who react to objects within their environment such as signs, instruments and symbols to bring about an outcome. An inherent limitation of the first generation of CHAT was its primarily individualistic focus in analysis (Olavarría, 2013). For this reason, Leont'ev decided to create a second generation of CHAT in order to get around this restriction.

Leont'ev (1978) created *the second version* of CHAT, which centres on the idea of activity. He stressed that instead of individual-mediated action, the basis of evaluation is expanded from an interconnected activity system. According to Leont'ev (1978), labour is basically cooperative and the primary distinction between one activity and another is found in the differences in their goals. By implementing community and division of work into Vygotsky's model, Leont'ev (1978) elevated the concept to the status of a systems approach.

Engeström (1999) developed *the third version* of CHAT, which extends the basis of evaluation to include relationships between several activity systems. He makes a difference between the growth of the basis of evaluation to include two or more linked activity systems from a single activity system. To do this, he put out a systemic model based on the first two versions of activity theory which integrated the laws, the division of labour, and aspects of the community. He emphasized the importance of understanding how interactions between individuals are influenced by objects, processes, laws, division of labour, and other members of the social environment within which learning activities occur. This comprehension is essential for understanding human existence and development, as well as for creating conditions conducive to improvement. According to Engeström (2001), in order to handle conflicts and irregularities that promote shared learning via change, CHAT should consist of several networks of interacting systems. As a result, a successful method for learning activities was established by the third version of CHAT (Barma, 2011). Through the use of CHAT, practitioners have the opportunity to engage in introspective study and scholars can evaluate complicated and developing professional behaviours (Foot, 2013; Yliruka & Karvinen-Niinikoski, 2013). Humans learning by doing, participating in groups, and communicating via their activities are the three main tenets of CHAT (Foot, 2014).

3.3 The Activity System

The activity system according to Engeström (1987), serves as the core analytical unit in CHAT. The activity system yields quite several actions that are routinely carried out with minimal change as time goes by until eventually, they develop into automated processes that are taken for granted (Engeström et al., 1995). In addition, activity systems depict group activities carried out by players with various roles, places, and viewpoints (Foot, 2014).

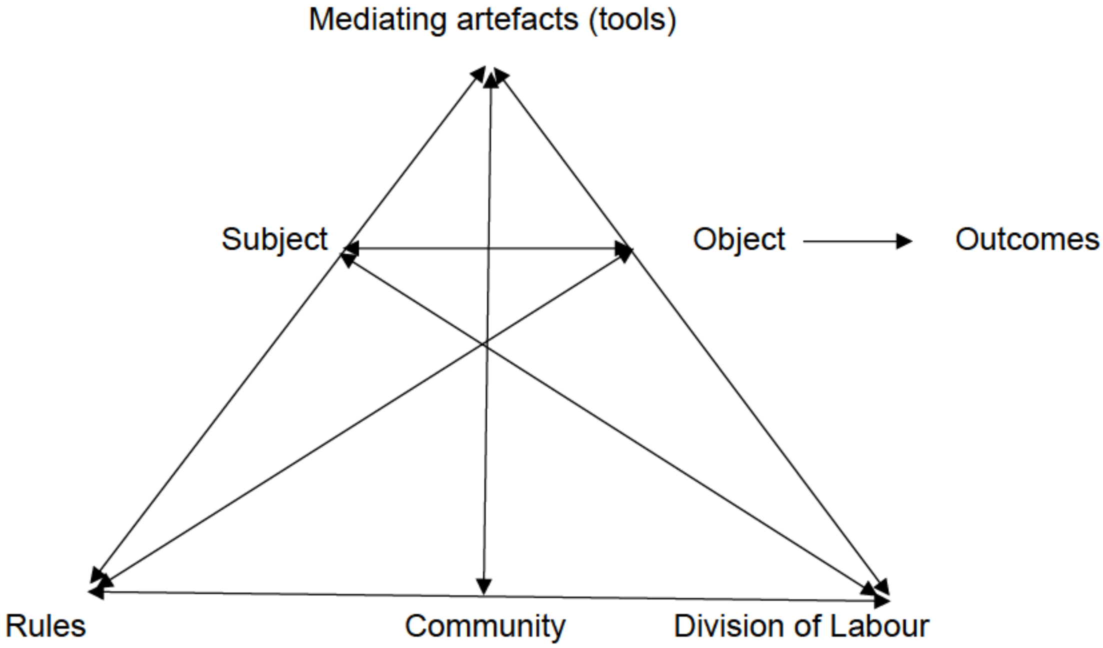
Within CHAT, the activity system functions as the primary focal point for analysis (Engeström, 1987). In such a system, various activities are created, frequently repeated with limited variation. These actions progressively transition into automated procedures and regular routines that are deeply embedded and considered as given (Engeström et al., 1995). Activity systems also depict collaborative endeavours carried out by individuals holding varied roles, positions, and viewpoints (Foot, 2014). Furthermore, it has six fundamental elements, each holding cultural and historical dimensions and they include subjects, objects, tools/artefacts, community, rules and allocation of labour, as depicted in Figure 3, which presents Engeström's activity systems model, this framework is rooted in Leontiev's exploration of the collective nature of human activity.

The picture demonstrates how many elements such as artefacts, regulations, community, and allocation of labour act as mediators in the relationships between the subject and the object rather than the other way around. The triangle's arrows indicate that the elements do not have a fixed position functioning alone without the other but there is an interactive relationship between the components and this defines the activity system as a whole (Olavarría, 2013).

As a process facilitated by devices used to achieve the objective (result), the upper portion of the triangle represents the collective activity of actions carried out by individuals (subjects) motivated by a goal or directed towards resolving a problem (object) (Gretschel et al., 2015). On the other hand, the regulations that control the activity itself and the allocation of labour among community members are shown in the lower half of the triangle.

Figure 3.1

Activity System



Learning by expanding (Engeström, 1987, p. 178.)

3.3.1 The Six Elements of an Activity System

The six fundamental elements of an activity system are subject, objects, tools/artefacts, community, rules, and division of labour.

Subject

The person or groups of individuals involved in the activity system are the subject (Trust, 2017). However, for Olavarría (2013), subjects are people or groups with the same goals or objects who are engaging in an activity. Through their engagement with the various components of the activity system, the subjects' identities and knowledge are sculpted and modified as they pursue the objects (Trust, 2017).

3.3.1.1 Object

Vygotsky's (1978) and Leontiev's (1978) concept of object-oriented activity served as the foundation for CHAT. As stated by Leontiev (1978), an external object that is the result of the activity system is what organises, motivates, and directs human behaviour (Trust, 2017). Also, the purpose of the participants' (subject) involvement in the activity system is the object (Olavirria, 2013). The concept behind the object provides an understanding of the motivations for various behaviours taken by individuals. Objects are being transformed into outcomes as a result of the motivation they get from the subjects (Trust, 2017).

3.3.1.2 Tools/artifacts

Tools/artefacts are materials or symbolic tools that bring about interaction between the subject and the object (Barma, 2011). Tools/artefacts form a way to motivate subjects with the aim of enhancing collaborative activity and instructive methods (Oliveira et al., 2011). On that note, there are three types of tools: psychological, physical, and abstract (Vygotsky, 1978). Psychological tools which are mental representations and symbols are cognitive methods which are employed to master higher mental functions (Vygotsky, 1978; Tust, 2017). Material devices are physical objects in the external environment and they can be computers, books, symbols, works of art and so on. A tool can also be a concept or theory. A tool that is selected by a subject determines how the subject acts within the activity system.

3.3.1.3 The Community

The subjects' broader social group, the community, has a major impact on the other components of the activity system (Ramugondo & Kronenberg, 2015). A community is the social circle to which all subjects participating in an activity belong with each having their own traditions, interests, and points of view. However, due to no one having all the information and abilities required to do every action inside the activity system, members of a community perform a variety of roles according to their knowledge and abilities (Trust, 2017).

3.3.1.4 Rules

Rules govern how the individual interacts with other participants in the activity and behaves towards an object (Foot, 2014). Also, it gives people guidance on how to engage in a community as members in an efficient manner (Olavirria, 2013). Rules are all the guidelines and instructions that influence the activity system. The association between the subject and the community is affected by regulations, which consist of arrangements among community members responsible for what, when, and in what order. Rules are produced externally, often by school management, boards of governors and ministries of education (Miles, 2020). Rules are instructions for taking actions, behaving, and engaging within a community that can be comprehended intuitively or explicitly (Trust, 2017).

3.3.1.5 The Division of Labour

The division of labour establishes the allocation of duties and responsibilities among system users during an activity (Batiibwe, 2019). This also shows how different actors have varied roles, tasks, positions, and responsibilities (Kamanga & Alexander, 2021).

The relationship between society and the object is facilitated through the distribution of labour (Miles, 2020). Divisions of labour have to do with the way duties are distributed among community members with equal status horizontally and this is known as the horizontal division of tasks. In addition, the distribution of tasks along power, position, resource, and incentive axes can also occur vertically.

3.4 Contradictions in CHAT

In contrast to issues or conflict, contradictions are structurally embedded tensions that evolve overtime within and among activity systems (Engestöm, 2001, p. 137). Kuutti (1996) describes analytical application of contradictions in the CHAT framework:

Contradiction is a term used by CHAT to describe a mismatch between elements, within them, across activities, or amongst developmental stages of a single activity. Contradictions show up as issues, breaks, failures, and confrontations. However, contradictions are seen by CHAT as opportunities for growth; activities are essentially always engaged in reconciling them (p.92).

Conflicts or tensions can be seen to bring about innovation in an activity system and also provide emergent prospects for the activity's advancements (Foot, 2014). Also, it helps in understanding shifts in activity systems (Foot & Groleau, 2011). Contradictions bring about opportunities for change, action and development of an activity (Blackler, 2009). Rather than being a flaw, activity theorists see contradiction as an indication of richness, mobility and an activity's potential for growth (Karanasios et al., 2017). Foot (2014) explains that contradictions within an activity system are not indicators of failure; instead, they serve as starting points for further development. These contradictions can arise within individual elements of an activity system, between different elements, and even between distinct activity systems (Olavirria, 2013). Concepts of contradictions are used within the context of education for learning to emerge for the purpose of solving the contradiction. Engeström (2000) explains:

Discerning contradictions within an activity system facilitates the concentration of practitioners and administrators on the underlying causes of issues. A common vision for the total resolution of the contradictions must be developed through such cooperative study and modelling (p. 966).

The proper resolution of contradictions results in the evolution, progress, and growth of an activity system (Kamanga & Alexander, 2021). Expanded learning is the use of contradictions to foster learning and change (Engeström et al., 1999). Also, expanded learning is the process of creating and resolving progressively evolving contradictions (Engeström & Sannino, 2010 p. 7), or learning about "what is not yet there" (Engeström, 2011, p. 74). Primary, secondary, tertiary, and quaternary contradictions are the four layers of contradictions that Engeström (1987) claims exist in any collective activity. Table 3 provides an explanation of each of these levels in connection to the current investigation.

Primary contradictions have to do with conflict within a given node in an activity system (Jones, 2014). It alludes to internal contradictions that exist within each of the main activity system's components. The primary contradiction permeates all aspects of the activity systems (Engeström, 2001, p. 137). *Secondary contradictions* emerge when two nodes within the activity system are in disagreement, resulting in conflict between two or more elements (Foot & Groleau, 2011), such as conflict between subjects and tools. *Tertiary contradictions* happen when an object from a more culturally sophisticated activity incorporated into an activity system (Engeström, 1987) is introduced into that system. It has to do with changes in activity over time (an activity evolving thereby making the later versions conflict with previous versions). *Quaternary contradictions* arise between the central activity and its adjacent activity systems (Foot & Groleau, 2011), for instance, when the objectives of one group directly clash with the intentions of another.

Table 3.1 shows how the four levels of contradiction are related to this present study.

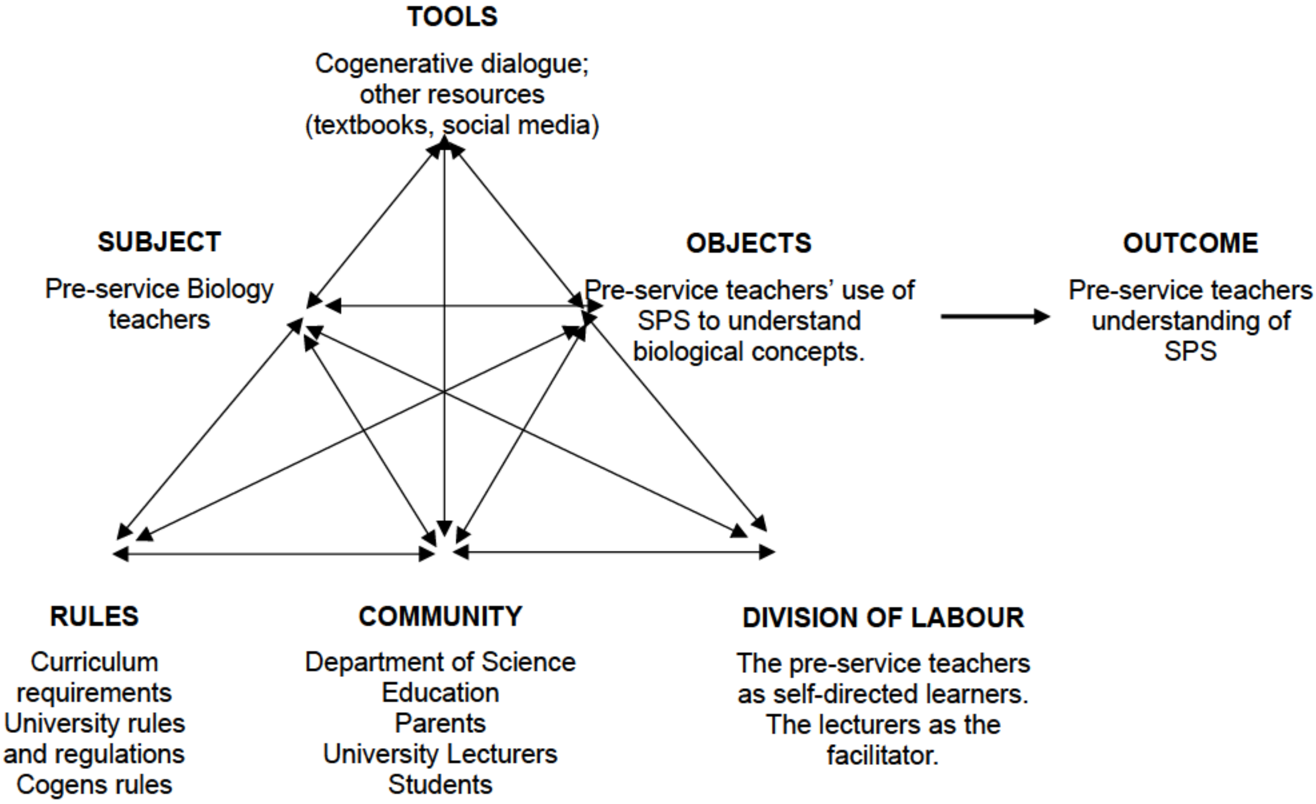
Table 3.1

The Four Levels of Contradiction in Relation to This Present Study

Contradictions Level	Relation to the present study
Primary Contradiction	This involves the use of cogens rather than the regular method of teaching
Secondary Contradiction	Conflict between lecturers and students in the university setting due to the introduction of cogens.
Tertiary Contradiction	Introduction of cogens instead of the regular method of teaching and how does this new method influence pre-service teachers' use of SPS?
Quaternary Contradiction	Introduction of cogens within the University setting as there may be rules by the University against the use of cogens in classrooms.

Figure 3.2

Activity System for This Present Study



The primary objective of this research was to examine how pre-service teachers utilize science process skills (SPS) in comprehending biological concepts. To achieve this aim, the perspectives of these pre-service teachers were examined through their participation in cogenerative dialogues and focus group interviews.

The activity system under investigation in this study was the classroom learning environment, where cogens were used to get how pre-service teachers use SPS to understand biological concepts. *The tools* utilized in this study to facilitate teaching and learning included group discussions, the use of textbooks, and the utilization of social media. However, the primary tool introduced to enhance the activity system and foster a deeper understanding of science process skills (SPS) was cogens. *The subjects* are the lecturers and pre-service teachers in relation to the use of SPS to understand biological concepts. The *object* is the pre-service teacher's use of SPS to understand biological concepts. *The outcomes* involve pre-service teachers possessing relevant SPS thus making it easy for them to understand biological concepts.

In terms of *community*, numerous communities are expected to influence the activity system both within and outside the classroom environment. These communities encompass pre-service teachers, lecturers, fellow students, university staff, the Department of Science Education, parents, and other significant relationships associated with each subject beyond the student affairs program. *The Rules* concerning this present study are how the lecturers abide by the University rules when carrying out cogens and also with the curriculum requirements of teaching SPS to students. Cogens rule should also be followed by both the lecturers and the pre-service teachers, and they should also be cautious of the time allocated for each cogen session. Cogen provides an opportunity for the *Division of labour* to be shared among the pre-service teachers as self-directed learners and the lecturers as facilitators. To be part of this activity system, the member must be a lecturer in the Department of Science Education, teaching biology and also pre-service teachers in their third and fourth year who were ready to participate in cogens.

3.5 Biological literacy as a framework for the Study

The examination of plants and animals falls under the domain of biology, a field that plays a crucial role in fostering the scientific literacy necessary for national progress (Akintola, 2018). Biology serves as a fundamental and pragmatic discipline that enhances our understanding of life across various scales, spanning from molecular biology to global interactions (Kampourakis & Reiss, 2018). In addition, one of the prerequisites for studying science and science-related courses at tertiary institutions is biology.

The NPE (FRN, 2013) states that studying biology will give students the necessary laboratory and field skills, significant and pertinent biological knowledge, and the development of useful scientific attitudes. As a result, knowledge of biology is crucial for students as future leaders to make judgments in their daily lives that are motivated by biology (Semilarski & Laius 2021).

According to Fan and Geelan (2013), scientific literacy is being able to apply scientific information to improve decision-making abilities and comprehend the essence of science. Scientific literacy is important because an individual is able to apply the knowledge of science to human daily activities at home, school, and industry (Akintola, 2018).

A subcategory of scientific literacy is biological literacy. It involves people and the need to acquire biological attitudes, abilities, and knowledge in order to engage in biological arguments. Additionally, it entails the integral acquisition of problem-solving and decision-making skills essential for navigating daily life (Miller, 2011; Uno & Bybee, 1994). Uno and Bybee (1994) further underscore the importance of biological literacy, as it empowers individuals to engage in logical and critical reasoning when confronted with biological challenges in their everyday experiences. Besides, Onel and Durdukoca (2019) pointed out that one must comprehend the fundamental ideas of biology, the evolution of biological concepts across time, and the importance of biology in order to be considered biologically literate. A person with a strong background in biology is capable of performing tasks, including analysing and categorising scientific research, planning experiments, analysing data, and drawing conclusions—all of which are components of SPS.

Uno and Bybee (1994, p. 554) classified biological literacy into four distinguishing levels; these levels and their characteristics are explained in Table 3.2.

Table 3.2

Levels and Characteristics of Biological Literacy.

Level	Characteristics
Nominal biological literacy	• Students can recognise biological terminology • They have naive definitions and misconceptions of biological concepts
Functional biological literacy	• Students can proficiently employ biological vocabulary • Accurately define biological terms • Memorise appropriate definitions of biological concepts
Structural biological literacy	• Students comprehend conceptual frameworks, procedural knowledge and skills in biology • Understand conceptual diagrams in biology. • They can articulate biological concepts in their own language.
Multi-dimensional biological literacy	• Students are able to understand the significance of biology in relation to other disciplines • Know the history and characteristics of biology • They can understand the intersections between biology and society

Note. Adapted from *Understanding the dimensions of biological literacy* by Uno and Bybee, 1994, p. 554.

I explained each of these levels of biological literacy in relation to my study.

3.5.1 Nominal Biological Literacy

A nominal level can be regarded as the entry level of students registered for biology. At this level, in-training educators are expected to understand the term plant taxonomy, which is the topic used in this study as biological in nature. For instance, pre-service teachers can define the concept of plant taxonomy but have little knowledge of its meaning.

3.5.2 Functional Biological Literacy

At this level, in-training educators can now define plant taxonomy correctly and this may be due to a better understanding of the topic through teaching and reading.

The pre-service teachers used for this study were those in their third and fourth years and plant taxonomy was a topic being taught in the third year.

3.5.3 Structural Biological Literacy

The in-training educators at this level can explain plant taxonomy and other sub-topics under plant taxonomy such as characteristics of plants, taxonomy, classification of plants and the importance of taxonomy on their own. Through SPS activities such as practical activities where they are being asked to classify different types of plants, in-training educators grasp the topic in breadth as well as depth. While doing these, the pre-service teachers can acquire both knowledge and SPS which enable them to understand plant taxonomy more fully and deeply. They can explain its meaning in their own words and also relate it with other biological concepts.

3.5.4 Multidimensional Biological Literacy

At this stage, students already comprehend the position of biology among other disciplines. The pre-service teachers can at this level carry out further investigation on plant taxonomy and they can relate plant taxonomy to social and ethical concerns.

They can discuss plant taxonomy, its characteristics, historical development and importance with their peers and lecturers. They can even take on projects of further investigation of plant taxonomy in their various communities.

3.6 The Primary Phenomenon Studied: Science Process Skills within the Context of Nigeria Curriculum

Science process skills (SPS) are a core part of the Nigerian curriculum and have a massive influence on how science is taught (Ango, 2002). These abilities provide a practical method for teaching and studying science that extends beyond simple theoretical ideas. Examining the incorporation of SPS into the curriculum in Nigeria necessitates the development of new national science curricula and a reconsideration of how they are presented in textbooks (Arkın, 2013). This should consider SPS as the foundation from which appropriate science activities are developed, with the ultimate goal of enhancing science process abilities. It is advisable to utilize the science lessons delivered in science classes (Nyakiti et al., 2010). Enquiry-based learning is built upon the foundation of SPS.

Enquiry-based learning represents an educational paradigm characterised by a pronounced emphasis on active student involvement within the learning process (Wulf, 2019). This pedagogical approach underscores the centrality of encouraging students to pose questions, delve into subjects, and undertake investigative endeavours. It fundamentally aligns with a student-centric educational philosophy aimed at nurturing curiosity and promoting critical thinking (Schwartz et al., 2021). Consequently, enquiry-based learning stands as an educational framework devoted to cultivating students' capacity to formulate enquiries, probe complexities, and independently seek resolutions through experiential exploration, as opposed to the more traditional, passive receipt of knowledge from instructors.

To understand how to do science, one must become proficient in the scientific enquiry process and its application (Ebenezer et al., 2011). Teachers who possess the necessary science process skills can instruct successfully and have successful pupils (Ferreira, 2004). In other words, to attain a comprehensive grasp of the scientific method, one must cultivate expertise in the scientific enquiry process and its practical application. Teachers who are adept at the requisite SPS are well-positioned to deliver effective instruction and thereby facilitate successful academic outcomes among their pupils.

SPS encourage students to actively engage in scientific concepts through hands-on learning. Students obtain firsthand knowledge of scientific phenomena by using skills, including observation, measurement, and experimentation (Idris et al., 2022). These competencies frequently entail tangible, experiential activities in which students engage directly with materials, conduct experiments, and procure empirical data. The application of these skills renders students active participants within the pedagogical process, as opposed to passive recipients of information (Rambuda, 2006). They engage substantively with scientific principles through the formulation of hypotheses, experimental validation, and systematic scrutiny of outcomes. This hands-on methodology catalyses the cultivation of profound comprehension regarding scientific concepts, while simultaneously fostering critical thinking and problem-solving abilities

SPS constitute an elemental facet of interactive, experiential learning in the domain of science education, facilitating students' immersion in the exploration and application of scientific tenets. These proficiencies are typically honed through practical, hands-on activities and empirical enquiries. Students are prompted to proactively interface with scientific concepts by applying these competencies in authentic contexts. For instance, in a biology class, students might conduct experiments to observe plant growth, document data, and evaluate findings. Similarly, in a physics class, they may undertake measurements of the velocity of moving objects. These exercises not only reinforce their scientific erudition but also stimulate active learning, intellectual curiosity, and the acquisition of a deeper comprehension of the subject matter (Alake-Tuenter et al., 2012). SPS serve as instruments empowering students to actively investigate, grasp, and apply scientific principles through tactile learning experiences (Akcay & Akcay, 2015). These proficiencies stand as cornerstones of science education, nurturing inquisitiveness, curiosity, and the capacity for analytical thinking and problem resolution within the domain of science (Rambuda, 2006).

Teaching pupils how to participate in enquiries is one of the most important objectives in science education. This is made possible by teaching students the scientific method (Hernawati et al., 2018). SPS refers to technical abilities, investigative and experimental scientific habits of mind, or scientific enquiry skills (Idris et al., 2022). This supports the curriculum's objective of fostering a practical, in-the-real-world understanding of scientific principles. Construction and reconstruction of previously held personal conceptions are key steps in the learning process of science (Hwang et al., 2012). It is a continuous process of enhancing existing knowledge and constructing concepts within complex, organized networks that are individualized to each child, have used input from outside sources, and have explanatory and predictive abilities (Leow, 2015). The ability to think critically and solve issues is also enhanced by SPS. Pupils acquire knowledge about how to elicit information, formulate hypotheses, and evaluate data (Diani et al., 2020).

The Nigerian curriculum places a strong emphasis on these abilities, which are crucial for doing scientific research and encouraging independent thought. The relevance of science-literate people possessing SPS and employing the enquiry method as a teaching method during courses is widely emphasised, according to the study done by Akben (2015). However, it becomes evident that the experiments outlined in textbooks often adhere to the structured inquiry level when examining the extent to which this approach is integrated into course materials and key resources. Consequently, students may only develop rudimentary skills. The goal of Akben's (2015) study was to help aspiring classroom teachers realise that by taking a critical look at the experiments in textbooks, they can create new experiments. The principles of science education are logic, problem solving, and procedures. As a result, teaching students SPS is one strategy to influence their science skills (Hernawati et al., 2018). Wahyuni et al. (2017), emphasise that students must internalise, practise, and own their SPS. It refers to the scientific enquiry skills, experimental and investigative habits of mind, or procedural skills demanded of science students. Therefore, a key function of science education is to provide students with knowledge of the scientific method (Ekici & Erdem, 2020). Gunawan et al. (2019) added that SPS serve as a crucial marker of the success of educational objectives.

SPS offer a platform for using scientific knowledge with real-world applications. The SPS serve as the cornerstone for this attempt (Granell et al., 2020). The curriculum emphasises on providing students with skills transferable to a wide range of sectors. According to Baldwin and Wilson's (2017) research, using a shared textbook technique helped students develop their science and literacy abilities in order to assist future science learning. Also, by relating the topic to their everyday experiences through the practical and outside activities, students were able to overcome expectations.

The ideal period to introduce science to young children is in the preschool years (Hayes et al., 2022).

The Nigerian curriculum follows international trends in education by emphasising skill-based learning rather than just concentrating on the acquisition of scientific knowledge (Okolie et al., 2021). The curriculum is in line with international advancements in education thanks to the incorporation of SPS, which also helps students get ready for future careers in science and technology (Mickimm & Forrest, 2013). SPS prepares students for future employment in science and technology in addition to academic advantages (Hall & Miro, 2016). The curriculum's goal of educating kids in STEM fields, where SPS are essential, is in accordance with this method. A major goal is scientific literacy, especially in this day of information overload (Hall & Miro 2016). Nigerian education strives to produce citizens who can assess scientific data critically and make wise decisions. By fostering an awareness of the scientific method and the capacity to evaluate scientific claims critically (Pedro et al., 2019), SPS play a significant role in helping to accomplish this. The curriculum also acknowledges the significance of including indigenous knowledge and practises in science education. Science can be made more culturally relevant and interesting for pupils by incorporating local contexts and traditional knowledge into SPS (Chinn, 2007).

Science process skills are an essential component of the Nigerian curriculum, not only a theoretical foundation (Ango, 2002). They support the objectives of practical application, critical thinking, experience learning, and preparedness for further scientific study (Sinaga, 2021). The curriculum aims to generate scientifically literate citizens capable of advancing Nigeria's scientific and technological advancement by emphasising these skills (Suwono, 2016).

3.7 CHAT and Biological Literacy Relationship in this Study

When CHAT is employed within the educational system, it investigates how learning opportunities are transformed through the collaborative efforts of instructors and students to enhance educational environments (Murphy & Carlisle, 2008). The goal of this research was to explore how pre-service teachers use SPS in understanding biological concepts based on plant taxonomy. CHAT served as a valuable theoretical framework for my study as it involved the allocation of labour which was done among the pre-service educators and also class interaction through the use of cogens.

When working with interconnected activity systems as networks, Engeström's (2001) third-generation activity theory prioritises determining the role of discourse, various views, and questions of power. Engeström's (2001) research is unique in that it emphasises collective growth over individual growth. My study focused on that aspect since it was based on focus group discussion and explained how the participants could discuss how they use SPS to understand biological concepts based on plant taxonomy. The biological literacy model was suitable for this study because it was envisaged that the pre-service teachers used for this study fitted in at least one of the characteristics of the four stages of biological literacy proposed by Uno and Bybee (1994, p. 554).

3.8 Chapter Summary

In this chapter, I examined the theoretical frameworks guiding this study, namely Cultural Historical Activity Theory (CHAT) and Biological Literacy and also described science process skills as a conceptual framework within the Nigerian curriculum. These theories helped make sense of how pre-service teachers used SPS to understand biological concepts based on plant taxonomy. The following chapter, Chapter 4 presents the methodology adopted for the study.

Chapter Four: Research Methodology

4.1 Introduction

This chapter delineated the investigation methods utilized to achieve the objectives of this study. Researchers need a path through which they can conduct their research, and this is where research methodology comes in. It shows the procedure in which a researcher formulates problems and objectives and presents their findings from the data obtained during the process of carrying out the research (Kassu, 2019). Igwenagu (2016) simply describes research methodology as a guide to research and how it is being conducted.

In relation to the explanation above, I gave a detailed depth under the following subheadings, the methodology and procedures used during this study: research model, research method, research design, study sample and participants, data generation techniques, research instruments, pilot study, data analysis, rigour of the study; trustworthiness, credibility, transferability, dependability, confirmability, ethical consideration: authorisation of research, approval of data collection from correspondents, secrecy and privacy, accuracy, data use and disposal, limitation of the study and summary.

4.2 Philosophical Perspective of the Study

The underlying philosophy of this research was constructivism (or interpretivist paradigm) inextricably intertwined with a transformative perspective, which recognises that interactions and experiences lead to the social construction of knowledge (McNamee, 2010; Mezirow, 2018). Rooted in social constructivism, the study acknowledged the subjective nature of reality, valuing participants' perspectives as critical components for understanding how pre-service biology teachers construct their understanding of science process skills (SPS) in plant taxonomy. By embracing these philosophical tenets, the research aimed to explore not only the current understanding of SPS among pre-service teachers but also to influence how these participants view and engage with these skills within their teaching practices. The transformative perspective played a key role in this by seeking to address a broader educational need:

the enhancement of SPS teaching in biology education. This perspective is embedded in the study's effort to challenge and potentially shift participants' approaches to SPS, fostering a deeper, more effective integration of these skills into their professional practices.

Thus, the study navigated the complexities of knowledge formation, emphasising the contextual and relational aspects inherent in the participants' interpretation of SPS. It also aimed to contribute to a broader educational transformation by encouraging more reflective and empowered teaching practices among future biology educators.

4.2.1 Constructivist Philosophical Perspective

This study, grounded in a constructivist philosophical perspective, acknowledged that knowledge emerges through social interactions and lived experiences (Cupchik, 2001), a lens vital for understanding how pre-service biology teachers use science process skills (SPS) in plant taxonomy. The strength of constructivism lies in its emphasis on the contextual and socially embedded nature of knowledge formation, allowing for an in-depth exploration of individual perspectives (Mensah, 2015). However, its potential weakness lies in subjectivity, potentially introducing bias (Roulston & Shelton, 2015). To address this, the study employed methodological triangulation, combining focus group interviews, open-ended questionnaires, and cogenerative dialogues. This multifaceted approach enhanced credibility and reduced the impact of individual bias, ensuring a more robust interpretation of how SPS are constructed by pre-service teachers. By embracing constructivism, the study navigated the knowledge construction, recognising the dynamic connection between individuals, their learning environment, and the conceptualisation of SPS in the specific context of plant taxonomy education.

4.2.2 Transformative Paradigm and Participatory Inquiry Paradigm

The present study is embedded in a qualitative research approach (as we shall discover in Section 4.3). As referred to earlier, it has also assumed a *constructivist stance*. That said, though the stance thereof is suitable for that kind of research, it is lacking concerning “acknowledgement of experiential knowing; that is, knowing by acquaintance, by meeting, and by felt participation in the presence of what is there” (Heron & Reason, 1997, p. 277). Thus, the study needed to adopt *Transformative Paradigm* intertwined with the *Participatory Inquiry* Paradigm (PIP) to offer a thorough and all-encompassing investigation of the use of science process skills (SPS) by pre-service biology teachers in understanding plant taxonomy.

Transformative Paradigm, enriched by a dedication to promoting social justice, offers a framework to unveil and challenge inequities (Jemal & Bussey, 2018). Yet, its potential weakness is the complexity of instigating transformative change (Grin et al., 2010). To address this, the study integrated a cogenerative dialogue (see Section 4.4 for this mechanism and methodological procedure), empowering participants to collaboratively shape educational practices. Aligning with transformative philosophy, the research aimed to unravel power dynamics influencing SPS comprehension and the subsequent understanding of biological concepts. By fostering participant-driven discussions, the study endeavoured to overcome the weakness by empowering the present teachers to actively contribute to the transformation of their educational landscape. In embracing transformative philosophy, the research endeavoured not to only understand but also to catalyse positive shifts in how SPS are perceived and aligned with the broader goal of fostering inclusive and equitable science education in a quest to understand biological concepts by the teachers.

As referred to earlier, simultaneously the research is embedded in *Participatory Inquiry Paradigm*, which fits with qualitative research approach, and whose aspects formed the basis for cogenerative dialogues. Pozzebon (2018, p. 283) eloquently articulated philosophical assumptions concerning PIP which were adapted from the work of Heron and Reason (1997). He drew from among others the aspects of *epistemology*, *methodology*, *nature of knowledge* and *knowledge accumulation* to argue that Participatory Inquiry Paradigm embraces:

> *Subjective-objective and co-created reality ontology; an extended epistemology of experiential, presentational, propositional and practical ways of knowing; a methodology based on co-operative relations between co-researchers; and an axiology which affirms the primary value of practical knowing that flourishes with co-operation (p. 274; emphases added).*

4.3 Research Design

Research designs offer specific courses of action in a research enquiry, encompassing qualitative, quantitative, and mixed methods approaches (Creswell, 2014). A research design serves as the blueprint and groundwork for approaching and investigating a research problem.

The research designs that guided this study were case study and participatory action research types. Creswell (2014) identifies participatory action research to be one of the research designs in a qualitative study. In this study, a qualitative method of enquiry was employed, with participatory action research (PAR) and case study finding their conceptual roots in TP and PIP. PAR is among various designs within the realm of qualitative research (Mertens, 2015).

4.3.1 Case Study

This study adopted a case study research design. Various perspectives on case study within qualitative research have led to several definitions of the term, some of which may overlap or share similarities. Yin (2018) defined a case study as an investigative study that involves a thorough exploration of a modern occurrence within its genuine setting, especially when the distinctions between the occurrence and its setting are unclear. According to Creswell (2014), a case study represents a qualitative approach in which the researcher delves profoundly into a program, event, activity, process, or one or more individuals. They are characterized by specific timeframes and activities, requiring the researcher to gather comprehensive data using various methods over an extended period. Coombs (2022) went further to state that case study involves a thorough investigation conducted to gain insights into a real-life phenomenon.

These three definitions of case study resonate with my study that explored the use of science process skills (SPS) by pre-service teachers to understand plant taxonomy. The study entailed a comprehensive investigation into the use of SPS, development of SPS and factor that influenced the use of these skills by pre-service teachers to understand plant taxonomy. The group of people as stated by the authors above may be the 24 pre-service biology teachers. These participants were chosen because they already had prerequisite knowledge of plant taxonomy since they were already in their fourth and third year in a Nigerian University. The research was conducted within a university environment, which served as the real-life setting for the participants. Therefore, a case study design was deemed appropriate for this research.

It is noteworthy that case study research allows for multiple data generation and analysis (Coombs, 2022; Cohen et al., 2018; Creswell & Poth, 2016). Data was gathered in this study through multiple sources which includes open-ended questionnaires, focus group interviews and cogenerative dialogues. This allowed for deep insight into the use of SPS by pre-service teachers because, I thoroughly interpreted the uniqueness of each participants' beliefs, viewpoints and notions on the use of SPS and the factors that influenced them in form of themes during the data analysis of the focus group interview.

4.3.2 Participatory Action Research

Participatory action research, also known as classroom-based action research (Cohen et al., 2018), has been lauded as relevant and important in contemporary times in relation to teachers' actions and pedagogy and the implementation of evidence-based practices (Dana, 2016).

Participatory action entails the collaborative utilization of research, education, and action to gather information for addressing social or environmental issues and effecting change (Pain, 2011). Unlike merely providing information, Participatory Action Research (PAR) is characterised as transformative (Baldwin, 2012). Locke et al. (2013) and Kemmis et al. (2014) outline several principles of PAR, emphasising its social nature that revolves around the interaction between individuals and their social environment. PAR is pragmatic in that it aims to enhance social practices and individuals by encouraging self-directed efforts. Additionally, PAR is an approach encompassing learning, planning, action, analysis, and reflection, fostering a continuous cycle of planning, action, analysis, and reflection (Cohen et al., 2018). Pain et al. (2011) believed that PAR is well-defined because it is propelled by participants who have a vested interest in the topic being researched, it is collaborative at every stage, and it is aimed at bringing about improvement on the issues being researched.

PAR has been welcomed in educational settings in recent years as a tool for developing students' learning and teachers' successful instruction (Sokhanvar & Salehi, 2018). In addition to generating new knowledge, participatory action research (PAR) initiatives can contribute to promoting change in schools and among their stakeholders (Pine, 2009). A PAR initiative allows the teacher to fully engage students by becoming more collaborative, participatory, and democratising (Brydon-Miller & Maguire, 2009).

The primary aim of action research is to improve teaching practices by helping teachers develop the capability to make informed decisions and exercise judgment in complex human situations. It also contributes to the improvement of performance and the development of professional roles (Macdonald, 2012). Participatory Action Research (PAR) was well-suited for this study, given that the participants were pre-service teachers engaged in the teaching practice processes.

Participants in PAR are not subjects of research, but they contribute actively to the research process at all phases (Macdonald, 2012). PAR is applied research as it brings about practical outcomes and positive change (Walter, 2009). Participatory Action Research (PAR) demands a significant time commitment, necessitating participants to be aware of its time-consuming nature. Additionally, the researcher must possess a thorough understanding of the community chosen for the study (Macdonald, 2012). Gaining entry into the community is crucial, and it can pose a hurdle if the researcher is unfamiliar with the community context (Macdonald, 2012). Fortunately, this was not an obstacle for the current study, as I was well-acquainted with the community where the research took place.

4.3.4 Cooperative Participatory Action Research

Cooperative inquiry (CI) shares similarities with the concept of cooperative participatory action research (CPAR) (Mertens 2015). In CI, all individuals actively participate in the research process, although it does not explicitly focus on power dynamics and the potential transformative impacts of the research. CI is a systematic approach involving action and reflection by co-enquirers collaborating on a shared and compelling question (Ospina et al., 2008). As cooperative inquiry emphasises self-determination, all participants play a significant role in decision-making by contributing ideas, shaping and managing the project, drawing conclusions from their experiences, and acting as co-subjects involved in the researched activity (Reason & Bradbury, 2001).

PAR utilizes various data gathering techniques, encompassing, but not restricted to, focus groups, participant observation, field notes, interviews, diaries, personal logs, questionnaires, and surveys (Macdonald, 2012). as well as cogens (Park & Martin, 2018). In this study, the chosen data collection methods consisted of focus group interviews, questionnaires, and cogens.

4.4 Research Methods

Within this section, I describe the various stages undertaken in this study. These include the kind of data required in order to address the research questions in the study, the participants and the criteria for selecting them, data generation techniques, ethical measures employed in the study, ensuring trustworthiness of the result and result presentation of data analysis.

4.4.1 Participants and the Associated Selection Criteria

The sampling plays a significant role in generating, interpretating, and presentating data (Flick, 2014). In qualitative research, sampling is crucial as it allows researchers to select sample sizes and designs that are aligned with their research objectives (Omona, 2013). In this study, I utilized the purposive sampling method to select participants and the research site.

Purposive sampling involves the intentional selection of specific individuals, events, or settings because of the valuable data they can provide, data that may not be accessible through other means (Padgett, 2017). This method involves the deliberate selection of participants based on their distinctive characteristics and does not necessitate underlying theories or a predetermined number of participants (Etikan et al., 2016). Patton (2015, p. 264) explains that the logic and efficiency of purposive sampling involve the selection of cases rich in information for thorough examination. These cases provide valuable insights into issues essential to the study's objectives. Cresswell and Plano Clark (2011) added that purposive sampling enables researchers to identify and select individuals or groups familiar with a phenomenon of interest. The criterion for the selection of participants in this study was that they were pre-service biology teachers who did biology in their third and fourth years at the same university under study.

Convenience sampling method was also adopted for this study. According to Andrade (2021), convenience sampling refers to when data are being collected from a population element based on the fact that they are conveniently available to participate in the study. Cohen et al. (2011) added that convenience sampling involves selecting people as participants because they are easily accessible. The geographical location for this study, a university in the southwestern region of Nigeria, was conveniently selected as I was a lecturer of biology education at the same university. While this selection made logistical and economic sense, I recognize that it also introduces potential biases into the study, particularly researcher bias and response bias. There is a possibility that pre-service teachers, aware of my role as their lecturer, may have responded to focus group interviews and cogenerative dialogues that they believed would impress me, rather than expressing their true opinions. Additionally, there is a risk that my involvement in the research process could have unconsciously led to pre-conceived conclusions. To address these concerns, several measures were implemented:

Anonymity and Confidentiality: Participants were assured of the confidentiality of their responses and were explicitly informed that their participation or responses would have no impact on their academic standing.

Neutral Questioning: The questions used during the focus groups and cogenerative dialogues were carefully designed to be neutral and open-ended, reducing the likelihood of leading participants towards specific responses.

Reflexivity: Throughout the research process, I engaged in reflexive practices, consistently reflecting on my dual role to minimize any undue influence on the research outcomes.

Transparency and Independent Verification: The research process was conducted with transparency. The data analysis was not only independently reviewed by colleagues who were not involved in the study but also by my supervisor, ensuring that the findings were not unduly influenced by personal biases.

These steps were taken to mitigate the potential biases inherent in conducting research in a familiar setting and to ensure that the findings of this study are as reliable and valid as possible.

In qualitative research, it is essential for the researcher to carefully determine and validate the appropriate sample size (Marshall et al., 2013). Boddy (2016) emphasised that the sample size in qualitative research should be sufficient but not excessively large, generally exceeding 30 participants. Dworkin, (2012), therefore made a recommendation of 25-30 participants.

The individuals involved in this research comprised 24 pre-service biology teachers currently in their third and fourth academic years at the university. Specifically, this group consisted of 12 students from each academic level (i.e., third and fourth year), selected based on their achievements in biology. The participants were selected based on their academic performances (i.e., top-, middle- and lower-mark distribution). These groups were chosen because of their extensive experience (of at least 3 years) in the development of SPS. It should be noted that this group of participants had been taught SPS during their practical and teaching method classes over the three years. Furthermore, the topic of interest plant taxonomy is normally offered in the third year of their degree. The participants were also more experienced than the lower-level ones in terms of participation in teaching practice.

4.4.2 Data Generation: Plan, Phases and Strategies

Data generation entails the structured collection of information from key sources to investigate the research problem and evaluate the outcomes (Dudovskiy, 2019). Byman et al. (2021) emphasise that researchers acquire data from the empirical field as part of the study. Kabir (2016) asserts that the ultimate aim of data collection is to capture high-quality evidence, enabling thorough data analysis and providing reliable answers to the study's posed questions. In this research, various data collection methods were employed, with careful attention to time considerations and ensuring that the collected data underwent adequate processing and storage for effective analysis. The data collection techniques utilised in this study included open-ended questionnaires, focus group interviews and cogenerative dialogue. Data collection entails the methodical gathering of information from vital sources to tackle the research problem and evaluate the outcomes, as outlined by Dudovskiy (2019). Having a well-defined data generation plan is essential to ensure comprehensive answers to all research questions. The specific data generation plan for this study was presented in Table 4.1.

Table 4.1

Outline of the Research Questions and Methods Used for Data Generation.

Research Question	Methods Used to Generate Data	Justification for Use	Evidence Targeted
1. What were the pre-service teachers' (a) conceptual knowledge of SPS? (b) level of biology literacy within the context of plant taxonomy?	Open-ended questionnaires Biological literacy instrument	To gain deeper insights into the pre-service teachers' conceptual level of SPS (Miles, 2010).	SPS and Biological literacy level of the pre-service teachers Open ended questionnaires on the SPS developed by Pre-service teachers
2. How did pre-service teachers use SPS to understand biological concepts based on plant taxonomy?	Open ended questionnaires Focus group interview. Cogenerative dialogue	In-depth understanding of the SPS developed by the pre-service teachers (Tahir, 2017).	SPS developed by the pre-service teachers.
3. Which factors influenced pre-service teachers' use of SPS to understand biological concepts based on plant taxonomy?	Focus group Interview.	To offer a comprehensive and detailed information of the factors that influenced pre-service teachers' use (Mertens 2015).	Factors that influenced pre-service teachers' use of SPS for understanding plant taxonomy.

4.4.2.1 Pilot Study

Mertens (2015) emphasized the significance of ensuring clarity and conducting pilot testing for questionnaires in research. Doody and Doody (2015) noted that a pilot study provides important insights to guide researchers in conducting their research. A pilot study is a preliminary assessment designed to appraise different elements of the methods intended for a larger, more rigorous, or confirmatory investigation (Arain et al., 2010). They also emphasized that the purpose of a pilot study in research is to evaluate research instruments and methodology, as well as to uncover ethical and practical concerns that could impede the primary study.

Utilizing evaluation by a panel of experts in the pertinent field of study being targeted is another approach to establishing the face and content validity of an instrument (Creswell & Creswell, 2022). The pilot study in this research was not directly conducted on students, rather I had my tools (i.e. open-ended questionnaires and focus group interviews) refined based on the feedback gotten from my supervisor and colleagues who have experience in lecturing in sciences most importantly biology. The lecturers in the pilot study were invited to view the questions I constructed for the open-ended questionnaires, focus group interview and cogenerative dialogue. Some of my colleagues after going through the questions suggested the aspect of plant taxonomy that suits a particular skill.

For example, the questions I formulated for the focus group interview were all listed for the participants. My supervisor suggested I incorporate the elements of CHAT within the context of my study into the questions as now seen in Appendix E. Questions 5 and 6 in Appendix E read "What are the factors that influence your use of science process skills to understand plant taxonomy" and "How do the factors mentioned above influence your usage of science process skills for understanding plant taxonomy". These questions were removed and replaced with "Do you think your lecturers follow the rules concerning the teaching of plant taxonomy (e.g., curriculum requirements and the university rules concerning SPS, and cogen rules)". It was suggested that the previous questions were more of repetition and the latter would address the factors.

The pilot study helped me discover questions that might cause discomfort to participants, and these questions were subsequently eliminated. I made certain that my colleagues and supervisor provided their assessments of each question's effectiveness. I was able to make adjustments based on their input to guarantee that the tool could generate dependable and valid data.

4.4.2.2 Data Generation Strategies

4.4.2.2.1 Open-Ended Questionnaires

A questionnaire serves as a tool for collecting data and comprises a series of inquiries designed to gather information from respondents (Abawi, 2013). Researchers utilise questionnaires to understand people's beliefs or opinions across various research scenarios (Neuman, 2014). In the questionnaire format, respondents are responsible for reading, interpreting, and then providing written answers to the questions (Kumar, 2011). Kumar further emphasised that questionnaires should be developed in an interactive manner, with clear and easily comprehensible questions, and a user-friendly layout. Cohen et al. (2017) highlighted the qualities of effective questionnaires, emphasising that they should be focused, relevant, yield valuable data, and be respectful of respondents' time and energy (p. 498).

Mertens (2015) stated some advantages of questionnaires as being easy to compare and analyse, can be completed anonymously, and can also be administered to many people. When questionnaires are being administered, it allows the researcher to generate data that are specific to their own research (O'Leary, 2014). Since questionnaires incorporate a combination of open and closed questions for data collection, they allow for the acquisition of both quantitative and qualitative data (McLeod, 2018). Questionnaires have been used in different qualitative studies with different aims and research questions (Hagostrom, 2015; Eckerdal & Sundin, 2015).

Cohen et al. (2018) delineated various question and response formats used in questionnaires, including dichotomous questions, multiple-choice questions, rating scales, constant-sum questions, ratio data, closed questions, and open-ended questions. It's essential for the question types to be congruent with the research aim to guarantee the compilation of practical and pertinent data, as underscored by Champagne (2014).

An open-ended question is characterized by the absence of suggested answers, enabling respondents to offer their responses in their own terms (Popping, 2015). Such questions afford respondents the chance to provide a wide array of responses, including unexpected ones that might elicit further inquiries during interviews (Hyman & Sierra, 2016). Creswell and Creswell (2018) noted that qualitative researchers often employ open-ended questions to allow participants to express their perspectives. These questions may seek textual or numerical information and are commonly utilised in qualitative research methods and exploratory studies. Qualitative studies utilising open-ended questions enable researchers to gain a comprehensive understanding of the issues under investigation, as respondents can provide a broader range of options and opinions (Allen, 2017).

As this study adopts a qualitative research approach, data from pre-service biology teachers were collected using open-ended questionnaires. The specific open-ended questionnaires employed were:

1. Questionnaire for Pre-Service Biology Teachers on Science Process Skills
2. Science Process Skills Test (SPST)
3. Biological Literacy Instrument

Questionnaires on Pre-service Teachers on Science Process Skills

The questionnaire designed for pre-service biology teachers regarding SPS aimed to assess their conceptual understanding of SPS. This involved prompting them to provide definitions or explanations for key SPS concepts such as classification, measurement, operational definition, identification and control of variables, experimentation, hypothesis formulation, prediction, data interpretation, and observation. The questionnaire format was adapted from Emereole (2009) and was previously utilised by Miles (2010) in a study on in-service elementary teachers' familiarity, interest, conceptual knowledge, and performance on SPS. In both studies, participants were instructed to articulate their own definitions or explanations of the specified SPS concepts in the context of science.

A set of this questionnaire was distributed to 24 pre-service teachers, with the task of having them articulate their own definitions or explanations of SPS. This process was conducted in two separate sessions. Initially, the questionnaire was administered to pre-service teachers in their third year, followed by the administration to those in their fourth year. Each session lasted approximately 50 minutes, and the completed questionnaires were promptly collected for subsequent analysis. The questionnaire comprised two sections: the first section aimed to gather participant information, particularly their year of study. The second section contained nine SPS, allowing participants to provide written definitions or explanations for each process skill, thus assessing their conceptual understanding of SPS. The questionnaire underwent validation by my supervisor and a copy of this test is included as Appendix E (pp. 212 – 215).

SPS Test

Various researchers, including Akani (2015), Karamustafaoğlu (2011), Chabalengula et al. (2012), Tahir (2017), and Susanti and Anwar (2018), have utilised the Science Process Skill (SPS) test to assess students' SPS levels or those developed by them. In this study, the SPS test was employed to assess the SPS developed by pre-service teachers in comprehending biological concepts related to plant taxonomy. The SPS test comprised nine items, each addressing the specific SPS utilised in this investigation, namely observing, classifying, hypothesising, identifying and controlling variables, operational definition, interpreting data, experimenting, predicting, and measuring. Pre-service teachers were administered the test and tasked with responding to each question. The SPS test was structured as an open-ended questionnaire requiring participants to input their answers in provided spaces, as no options were given. Out of the 24 pre-service teachers who received the test, 22 attempted and returned the questionnaire, resulting in a response rate of 92%.

Some of the items on certain skills of the SPS test used in this study were constructed from various sources: some were adapted from several studies to suit plant taxonomy while some were formulated by using textbooks, the internet, past examinations and tests. The items were aligned with a particular set of objectives, each corresponding to the fundamental and integrated science process skills utilised in this investigation. This alignment is clearly detailed in Table 1 of (Chapter 2).

For observation, classification and predicting skills, I structured the question with the help of my supervisor using past examinations and tests on plant taxonomy. The items used for data interpretation in this study were modified from the research conducted by Shahali et al. (2017), who explored primary school teachers' comprehension of science process skills concerning their teaching qualifications and experience. While Shahali et al. (2017) used multiple-choice answers in their study, this research employed an open-ended questionnaire, omitting the option for predefined answers. The skill measurement test item utilised in this study was originally crafted by Enger and Yager (1998) and has been employed by various researchers. Additionally, operational definitions, hypotheses, and experimenting items were borrowed from Kazeni (2008), which drew inspiration from the Test of Integrated Science Process Skills (TIPS) developed by Dillashaw and Okey (1980). The test item on identifying and controlling variables was constructed using the internet following the objectives of the skill and about plant taxonomy.

The elements making up the testing tool were formulated to ensure impartiality towards any specific skill. To prevent bias, the test items underwent a comprehensive review by my supervisor and a copy of this test is included in Appendix G (pp. 218 – 225).

Biological Literacy Instrument

Biological literacy of the pre-service teachers was measured using a biological literacy instrument consisting of 4 items to address each level of biological literacy. This tool holds significance as it aids in assessing the extent of biological literacy among pre-service teachers. Two questions within the biological literacy instrument were borrowed from Illingworth et al. (2013), specifically addressing investigations into socio-biological literacy among both science and non-science students. The remaining two questions were personally crafted by me, drawing from the biology syllabus on plant taxonomy and relevant textbooks. As stated in Chapter 2, there are four levels of biological literacy, according to Uno and Bybee's (1994) model. A copy of the test is provided in Appendix H (pp. 226 – 227).

4.4.2.2.2 Focus Group Interview

Focus group discussion (FGI) involves a group of people participating in qualitative research being “interviewed” in a discussion setting (Neuman, 2014, p. 471). Focus Group Interviews (FGIs) serve as a means of eliciting qualitative data through informal discussions between the researcher and participants (Cohen et al., 2018). In conducting an FGI, the researcher brings together individuals who share common experiences or perspectives (Yin, 2014). Marshall and Rossman (2016) emphasised the importance of creating a relaxed atmosphere during the FGI to encourage participants to freely express their opinions on the studied phenomenon. In FGIs, the participants' perspectives take precedence, allowing their discussions to be centred around their agenda and facilitating interaction among themselves rather than solely with the interviewer (Cohen et al., 2018). Denscombe (2014) confirmed that the data sought by the researcher arises from the interaction within the group, emphasizing the importance of group dynamics in this context (p. 189).

The incorporation of a Focus Group Interview (FGI) was implemented as a data collection technique for pre-service biology teachers in their third and fourth academic years. This method aimed to produce high-quality information and enhance the study's findings. The FGI served the purpose of eliciting responses from pre-service teachers, addressing research questions two and three through the posed questions. These questions were related to how they used SPS to understand plant taxonomy and the factors responsible for how they used SPS.

A Focus Group Interview (FGI) involves a small assembly of individuals, typically ranging from six to nine participants, convened by a researcher to delve into their attitudes, perceptions, feelings, and ideas related to a specific research topic (Denscombe, 2007, p.115). Creswell (2014) suggests that a FGI can effectively gather data with a smaller group of four to six members. In forming the focus groups for my study, I took into account the recommendations of scholars. I organised four groups of pre-service teachers, each consisting of six members. This quantity facilitated easy group management and simplified the process of identifying participants' recorded audio voices during transcription.

Newby (2010, p. 350–1) and Gibbs (2012) suggest that Focus Group Interviews (FGI) should be held in an environment conducive to discussion, with a skilled moderator capable of encouraging participation, fostering thought and reflection, and maintaining accurate records of discussions. Homogeneity among participants is recommended, avoiding the inclusion of close friends or relatives (Neuman, 2014, p. 471). For the FGI in this study, participants were invited to a quiet classroom within the university premises. The venue was comfortable, and I facilitated the interview and discussions. Participants freely shared their perspectives on SPS, their utilisation in understanding plant taxonomy, and the factors influencing their usage. Prior to the FGI, participants received a consent letter ensuring the confidentiality of their responses and encouraging open and enriching contributions to the data.

As per Carey and Asbury (2016), Focus Group Interviews (FGI) play a role in diminishing power differentials between researchers and participants, empowering the latter and fostering collaborative research with them, rather than research conducted on them. Liamputtong (2011) supports this notion by asserting that FGI helps minimise the authoritative influence of the interviewer, allowing participants the freedom to actively participate in focused questions and discussions, thereby mitigating power imbalances between the interviewer and the interviewee. The issue relating to power was put into consideration during the FGI and this enabled the pre-service teachers to speak their views without reservations. I told the participants that I did not come as their lecturer but as a researcher who needed their opinions/views on the topic under study and so I wanted them to be as open as possible.

Creswell and Creswell (2018) emphasised the significance of researchers documenting interview information through handwritten notes, audiotaping, or videotaping. Punch and Oancea (2014) added that if an audio recording is chosen, the interviewer should inform the interviewee and be proficient in handling the audio device. Proper storage and transcription of recorded interviews are essential. In this study, I utilised a mobile phone voice recorder and a voice recorder on my laptop. To ensure functionality, I thoroughly tested the equipment multiple times. Following the entire interview process, I transferred the recorded interviews to my computer and two other devices for secure storage and transcription.

Although the estimated time for the interview was 45 minutes, none of the sessions lasted up to the proposed time, as most of the students were complaining that they were exhausted from the examination they had just finished. I also observed that participants had thoroughly explored the topics, and the conversation began to yield repetitive information, signalling that it was appropriate to conclude the discussion Appendix F (pp. 216 – 217) provides the FGI schedule questions for the pre-service teachers.

4.4.2.2.3 Cogenerative Dialogues in the Study

In this study, cogenerative dialogue (cogens) served as both a methodological approach for data generation and a mechanism for enhancing my PCK. Cogenerative dialogue is characterised as reflective discussions involving chosen participants with the goal of identifying areas of divergence that can be modified to enhance the quality of teaching and learning (Tobin, 2014). Cogenerative dialogues, or cogens, form part of a critical pedagogy process, allowing all participants to express their perspectives. Boss and Linder (2016) highlighted the effectiveness of cogens in transforming students' perspectives on learning both in and out of the classroom. Furthermore, cogens provide avenues for addressing social power dynamics within the learning environment (Bondi, 2013).

Cogenerative dialogue entails an interactive exchange among a select group of students, teachers, and researchers, where all participants contribute, listen, and learn from one another regardless of age, gender, ethnicity, or status (Hidayah et al., 2020). Cogenerative dialogue has emerged as a potent tool for educators and students across various educational levels (Bayne & Scantlebury, 2012).

The cogenerative dialogue conducted in this study involved interactions among the pre-service teachers, their lecturer, and myself. Before initiating the cogenerative dialogue, the lecturer delivered a lesson on a plant taxonomy topic covering taxonomy and systematics, the significance of plant taxonomy, and a list of plant taxonomy systems. The lecture lasted approximately 30 minutes, after which the cogenerative dialogues commenced with the pre-service teachers. The cogenerative dialogues unfolded in two sessions: one for pre-service teachers in their third year and another for those in their fourth year. I posed a series of questions to the pre-service teachers regarding the recently concluded lecture and various aspects related to utilising science process skills (SPS) in learning plant taxonomy.

In this study, both third-year and fourth-year pre-service teachers participated in the cogenerative dialogue following a lecture on plant taxonomy. It is important to note that while both groups had already been taught plant taxonomy by the time of the study, the fourth-year students had the additional benefit of having completed the course in their third year and potentially reinforcing this knowledge over time. This might have provided them with a slight advantage in terms of familiarity with the content and the confidence to engage in discussions. However, the study was not designed to compare the responses of third-year and fourth-year students. Instead, the focus was on understanding how pre-service teachers, as a collective group, engage with and apply science process skills (SPS) in the context of plant taxonomy. The insights gained from the cogenerative dialogues were intended to reflect the overall understanding and application of SPS among pre-service teachers, irrespective of their year of study.

While it is acknowledged that the fourth-year students' extended exposure to plant taxonomy and their additional academic experience may have influenced their responses, this was not a primary focus of the research. The inclusion of both year groups aimed to provide a broader perspective on the use of SPS in learning plant taxonomy, without explicitly comparing the two cohorts. This potential advantage for fourth-year students is recognised as a limitation of the study. Future research could address this by either focusing on a single cohort or by explicitly comparing different levels of exposure to content to better understand how prior knowledge and academic experience influence the use of SPS.

During the process of cogenerative dialogues, data were generated by taking pictures and audio recording the conversations between the pre-service teachers and myself.

4.4.3 Data Processing and Analysis

In qualitative research, data analysis entails the transition from raw data to comprehension, explanation, and interpretation of the specific case under investigation (Taylor & Gibbs, 2010, p. 1). The process of qualitative data analysis includes tasks such as organising and preparing the data, describing and presenting it, analysing, interpreting, drawing conclusions, and finally, reporting the findings (Newby, 2010; Creswell, 2012; Gibbs, 2012; Marshall & Rossman, 2016). For a qualitative researcher involved in data analysis, it is essential to identify and locate raw data while establishing connections between the data, research questions, and research findings (Gläser & Laudel, 2013, p. 5). According to Creswell (2013), a researcher must undertake the following tasks during data analysis:

- Arranging and structuring the data,
- Condensing the data into themes, and
- Presenting the data through figures, tables, or discussions.

In this study, all three of the mentioned tasks were carried out to address the four research questions posed. In the following sections, I elaborated on the methods used to analyse data for each phase of data generation.

4.4.3.1 Open-Ended Questionnaires

Questionnaire for Pre-Service Biology Teachers on Science Process Skills

The purpose of this section was to assess the open-ended questionnaires which explored the conceptual understanding of SPS among the pre-service teachers. This was accomplished by following the footsteps of Miles's (2010) research which used two major procedures to do a solid examination of the conceptual knowledge of SPS. The first procedure dealt with requesting that the participants describe or explain the following SPS classification, measurement, operational definition, identification and control of variables, experimentation, hypothesis, prediction, data interpretation, and observation whereas the second procedure utilises scholarly conceptual review and definitions of SPS as a reference to ascertain whether the answers derived from the participants are correct or wrong, in which case, accurate responses are marked as could define and incorrect answers are marked as could not define. The scholarly definitions that were used can be found under in Table 2.2 in the literature review. The definitions were taken from several research articles and books on the science process skills.

In the initial phase, 24 pre-service educators received a questionnaire and were instructed to articulate or elucidate their understanding of SPS in their own words. Following the administration of the questionnaire to third-year pre-service teachers, the same process was repeated with fourth-year participants. Each session had a duration of approximately 50 minutes, and the completed questionnaires were promptly collected for subsequent analysis. The questionnaire's first section aimed to gather information on the academic year of the participants, while the second section comprised nine SPS, prompting respondents to provide descriptions or explanations for each. This section was designed to assess their conceptual grasp of SPS. The questionnaire underwent verification by my supervisor (see Appendix D).

The questionnaires were assessed by aligning participants' responses with the SPS definitions outlined in Chapter 2. Responses that included key terms or ideas from the definitions were deemed correct, whereas responses lacking these key terms were considered incorrect.

Frequency and percentage distribution in excel were used to analysed and group the definitions given by the participants into two groups: could define and could not define.

Science Process Skills Test (SPST)

The data gathered from the study regarding the science process skills (SPS) developed by the pre-service teachers underwent an analysis through descriptive statistics, including means and frequencies. Dey (2003) suggests that enumeration and statistical analysis can be integrated into the analysis of qualitative data. Enumerating, which involves assigning numerical values to students' responses, formed the foundation for quantifying the data. This approach allowed us to aggregate frequencies of scientific skills derived from qualitative data concerning the practical that students found engaging.

Descriptive statistics in the form of percentages were used to describe the sets of categories formed from the data. The result from the data gathered were also represented in chart using excel spread sheet (see Figure 5).

Biological Literacy Instrument

Assessing the biological literacy of the pre-service teachers involved in this study was crucial. To gauge their level of biological literacy, an open-ended questionnaire was administered, consisting of four questions at each level.

The questions on the biological literacy tool were formulated to assess the four distinct levels of biological literacy and identify the specific level to which the pre-service teachers belonged. The test was given to the pre-service teachers in their respective academic years simultaneously, with proper supervision. Upon completion by the pre-service teachers in their third year, I collected the instruments and proceeded to administer the test to those in their fourth year. Each level of the test required approximately 30 minutes for the participants to complete the items.The test items contained 4 questions on each of the levels and the test was marked by assigning 5 marks to any correct answers. After marking, each item was evaluated based on the number of participants that answers the questions correctly which were represented as total pass and participants that did not answer the questions correctly were represented as total fail. Descriptive statistics (mean and percentage) was used to analyse the data and excel spreadsheets was used to represent the analysed results in a chart (see figure 6).

4.4.3.2 *Focus Group Interview*

The focus group interview with pre-service teachers aimed to understand how they apply science process skills (SPS) in comprehending plant taxonomy and to identify the factors influencing their utilisation of these skills. The initial step involved transcribing the audio recordings obtained during the interviews. Following Creswell's (2014) qualitative data collection process, which is inductive and moves from specific or detailed data (such as transcriptions or typed notes from interviews) to general codes and themes, the audio recording was transcribed verbatim to preserve the participants' exact voices. Subsequently, I thoroughly reviewed the transcribed data multiple times to extract meaning from the participants' responses, aligning them with the research questions. This process was essential for assigning codes and identifying commonalities within the data. I listened to each recording to get a general understanding of the content to familiarise myself with the discussion. I transcribed the recordings manually by listening to each segment and writing out the spoken words of the pre-service teachers verbatim without changing their responses. To ensure accuracy, I read through the transcribed data line by line to reflect what was discussed during the FGI. I went over the text paragraph by paragraph and section by section after the first transcription in order to understand the flow and context, which made it easier for me to pinpoint important themes and points.

I used a manual process to code all the data, although it took a lot of time. I chose to do this to get familiar with all the generated data as this made it easy for me to generate themes for the data. I carefully went over each transcript noting important words, and sentences related to my research topic by using coloured pens to label them. I developed a list of codes based on recurring themes and these codes were assigned to segments of text with similar ideas After coding the data, I grouped related codes into broader themes to identify key findings across the dataset. The data produced in this study underwent analysis through content analysis. Kumar (2014) defined content analysis as the method of examining interview content to discern the primary themes arising from the respondents' responses. Employing content analysis enabled me to condense the extensive data resulting from the focus group interviews. Following a meticulous examination of the core concepts within the data, I could then derive the themes necessary to address the research questions in this study.

4.4.3.3 Cogenerative Dialogue

Analysis of data from cogenerative dialogue was the same as the steps undertaken for focus group interview. The dialogue sessions were recorded, and the data were transcribed manually to generate themes.

4.4.4 Ethical Considerations

This study meticulously adhered to ethical considerations that guide qualitative research. Ethical principles in research dictate the appropriate and inappropriate actions for researchers in their conduct and behaviour during research (Cohen et al., 2018). These principles play a crucial role in safeguarding the interests of participants and serve as a framework for evaluating researchers' behaviour by establishing norms of what is ethical or unethical, right or wrong (Resnik, 2020). According to Creswell and Creswell (2018), researchers have a responsibility to honour the rights, needs, values, and wishes of the individuals providing information. Throughout this study, I ensured the utmost respect for the rights and needs of my participants. Various ethical considerations were carefully addressed, and the subsequent sections provide detailed explanations of these issues encountered during the study.

Obtaining permission before conducting a study in a specific location or setting is of utmost importance. Hesse-Biber and Leavy (2011) emphasized the presence of gatekeepers in research settings, underscoring the importance of obtaining their approval for access. Ryen (2011) noted that gatekeepers, occupying positions that allow them to grant researchers access to consenting groups in a given context, play a significant role. According to Creswell and Creswell (2018), gatekeepers are individuals at research sites who facilitate access and authorize the undertaking of a qualitative research study. These gatekeepers may include the heads of institutions or organisations where the study is to be conducted.

To secure permission for the study at the university, a formal letter requesting approval was composed and submitted to the institution's gatekeeper. The gatekeeper was kept well-informed about the study's essential details. Subsequently, a response was received, granting permission to conduct the study at the university. Following the gatekeeper's approval, an application for ethical clearance was submitted to the Human and Social Science Ethics Committee (HSSREC) at my university. The certificate confirming ethical clearance is included in this thesis (refer to the appendix for the ethical clearance certificate). For reference, a copy of the letter seeking permission from the gatekeeper is available in Appendix C, while Appendix A contains a copy of the gatekeeper's permission letter allowing the study to proceed.

Maheshwari (2013) stated that consent means offering participants the right to decline, participate, or withdraw from research, as well as an awareness of the key factors that would impact the decision to participate. Also, informed consent assures that study participants have of legal and mental capacity to assume responsibility for their participation in the study. Participants sign informed consent forms before participating in research (Creswell & Creswell, 2018). Manti and Licari (2018) emphasised that consent forms should be clearly written and understandable language for participants, and they should be provided with ample time to contemplate their participation. Consequently, the informed consent process should be appropriately organised to prevent participants from feeling coerced or unduly influenced to take part in the study. I provided a written informed letter to the 24 pre-service teachers for their signatures, outlining the study's purpose, objectives, the participants' option to decline or withdraw, and the timeframe for data collection in detail. After going through the form, the participants signed and returned the forms to me (see Appendix D).

There are two terms central to the protection of research participants and these are confidentiality and anonymity. In accordance with Mertens (2010, p.342), confidentiality entails ensuring the privacy of individuals involved in research and reporting their information in a manner that prevents their identification. Creswell (2012) further emphasises that while the lives and experiences of participants should be conveyed, the individuals from whom the research was derived must remain undisclosed. Sim and Waterfield (2019) add that confidentiality pertains to how a researcher handles information once it is in their possession and the extent to which this information is disclosed to others. Anonymity, on the other hand, implies that the data lacks unique identifiers, making it impossible for anyone, including the researcher, to trace the information back to the individual providing it (Mertens, 2010, p. 342). A researcher can practise anonymity by not using the names or any other personal information about participants' and this ensures the confidentiality of their identities.

In conducting this study, I prioritised upholding the confidentiality rights of the participating pre-service teachers. To preserve the anonymity of the participants, their names were omitted from the open-ended questionnaires, and during the Focus Group

Interview (FGI), there was no request to mention their names in the discussions. I did not have an intention of archiving the participants' details for any subsequent studies.

Participants received assurances that all data would be used for academic purposes only for the advancement of knowledge. Also, they were made aware that the data would be destroyed after five years of safekeeping at my university by my supervisor and thereafter disposed of, including the test results, questionnaire copies, and transcripts of interviews. All images and audio files from the FGI would be deleted permanently from all storage devices.

4.4.5 Trustworthiness of the Research Approach Adopted

The reliability of a study relates to the level of assurance in the data, analysis, and methods used, ensuring the study's excellence (Polit & Beck, 2014). Ibiamkwe and Ajekwe (2017) highlighted that trustworthiness in qualitative research revolves around whether the study effectively measures its intended objectives. In qualitative research, establishing trustworthiness involves considering factors such as reliability, applicability, dependability, and verifiability to support the research findings (Stahl & King, 2020). In accordance with Carter et al. (2024), triangulation serves as a strategy employed to gather data from diverse sources, aiming to achieve a comprehensive understanding of a study's subject or to assess validity by combining information from various origins. Triangulation entails cross-checking the themes and categories derived from various data collection sources in qualitative research or affirming data through diverse approaches (Creswell, 2012). The utilisation of multiple data sources contributes to the enhancement of credibility and the justification of evidence (Creswell & Poth, 2018). Yin (2014) categorizes triangulation into four types: data triangulation, investigator triangulation, theory triangulation, and methodological triangulation.

My study selected methodological triangulation. Data from focus group interviews, open-ended questionnaires and cogenerative dialogues were meticulously collated to gain a detailed grasp of the events, as portrayed by those who took part in seamless data analysis.

4.4.5.1 Result Credibility

Credibility, as defined by Lincoln and Guba (1985), pertains to the degree to which a research study faithfully represents the genuine meanings conveyed by research participants. In essence, credibility indicates the preciseness and truthfulness of the study's findings. In the realm of qualitative research, credibility is achieved when a study provides an accurate portrayal or interpretation of human experiences that individuals sharing the same experiences can readily identify with (Altheide & Johnson, 2011). The authors elaborated on strategies utilized to ensure credibility, which include reflexivity, member checking, and peer debriefing or scrutiny.

Member checking entails sharing interview data or initial findings with participants to validate the reliability of the data (Doyle, 2007). Lincoln and Guba (1985) underscored member checking as a crucial step in enhancing credibility in qualitative research. This process involves various activities, such as returning interview transcripts to participants and sharing synthesized findings (Birt et al., 2016).

To ensure the credibility of the investigation's results, I utilised diverse data-generating techniques, employed member-checked interview transcripts, and triangulated the collected data. Triangulation, as noted by Cohen et al. (2018), involves the use of two or more data gathering methods, thereby enhancing the study's credibility.

4.4.5.2 The Result Transferability

The transferability of research findings in a qualitative study refers to the extent to which the outcomes of the study can be applied to diverse settings, contexts, and inquiries (Coghlan & Brydon-Miller, 2014). It is demonstrated by giving readers proof that the study's conclusions may apply to other people, times, places, and circumstances (Ibiamke & Ajekwe, 2017). Kumar (2014) corroborated the idea of the earlier authors by stating that a qualitative study's replication in different contexts might be influenced by how thoroughly it is conducted. I carefully considered every aspect of this study, including participant recruitment, data collection, transcription, analysis, and note-taking. To make my theoretical framework applicable in a comparable setting and to support future research, I connected it with the work of other academics and gave a thorough explanation of every activity conducted in this study.

4.4.5.3 Study Dependability

Dependability, according to Ibiamke and Ajekwe (2017), involves accounting for all changes that take place in a setting and how they impact the manner in which research is carried out. To make it possible for future researchers to use a comparable research framework, the researcher must consider providing a thorough description of the study design and procedure. Dependability may be attained by offering a thorough and sequential description of the research procedures followed as well as the primary tools utilised to collect empirical data, such as the list of interview questions. I was able to keep an eye on every change that occurred throughout the research. When I reported the results, I gave thorough explanations of the background, the techniques and methodology, the sampling plans, and the analysis-related concerns.

4.4.5.4 Conformability of the Study

As per Kennedy-Clark (2012), confirmability implies that the conclusions of the study are grounded in the thoughts and experiences of the participants rather than the researcher's characteristics and inclinations. Bertram and Christiansen (2014) further noted that confirmability pertains to the degree to which the researcher's analysis can be corroborated by an independent third party. Anyone or any researcher may verify that the focus group interview was accurately transcribed. I also made sure that there was no form of fabrication and that my data was transparent.

4.5 Chapter Summary

This chapter provided an in-depth explanation of the qualitative investigation's methods and procedures employed in this research. It delved into the research design, sampling technique, methods of data generation, data analysis, and the appropriateness of the data tools used in the study. Nonetheless, the subsequent chapter focused on presenting and analysing the data with reference to existing literature.

In research, rigour implies that the researcher has employed suitable research tools to achieve the specified goals of the investigation. In the context of qualitative research, rigour serves as a means to instil trust or confidence in the research findings and enables the researcher to maintain consistency in the methods employed over time. Morse et al. (2002) delineate rigour as marked by the strength of the research design and the suitability of the method utilized to tackle the research questions. The authors emphasised that without rigour, research lacks value, veers into fiction, and forfeits its utility.

To ensure the rigour of this research, several data generating techniques such as focus group interviews and open-ended questionnaires (SPS test, pre-service teachers' conceptual knowledge of SPS) and cogenerative dialogue were utilised.

Chapter Five: Results

5.1 Introduction

This chapter presented analyses of data on pre-service teachers' science process skills (SPS) and biological concepts concerning plant taxonomy. In addition to summarising the collected data and information on how it was analysed, the chapter presented the teachers' conceptual knowledge of SPS, those (SPS) that were developed by pre-service teachers for understanding biological concepts, and how these skills were used to understand biological concepts. As the context is key in research studies such as this in which case study research design was adopted, the chapter further presented the factors that influence the teachers' use of SPS to understand biological concepts based on plant taxonomy.

The chapter is thus presented in three sections. The *first* section entails the pre-service teachers' conceptual understanding of selected SPS and their performance on these skills within the context of plant taxonomy. Evidence from open-ended questionnaires (see Appendix E) provided information on the teachers' conceptual understanding of the skills. Evidence from the SPS test (see Appendix G) provided the necessary information concerning the teachers' performance on the skill. The *second* section presents the results concerning the teachers' level of biological literacy. Open-ended questionnaires (see Appendix H) comprised questions based on the four levels of biological literacy (see Uno & Bybee, 1994, p. 554; Chapter 3, Table 3.2). The *third section* presents the findings on how the teachers used SPS to understand plant taxonomy-based biological concepts. The section also presents the findings concerning the factors that influenced the teachers' use of SPS to understand biological concepts based on plant taxonomy. Evidence from the teachers' focus group interviews and cogenerative dialogues provided complementary and supplementary information concerning the use of SPS to understand the biological concepts and the associated contextual factors behind them.

5.2 Pre-service Teachers' Science Process Skills

The data from the open-ended questionnaires were used to provide answers to research question 1 – What were the pre-service teachers' (a) conceptual knowledge of SPS, and (b) level of biological literacy within the context of plant taxonomy? Inherent in these questions is the assumption that students, in addition to content knowledge and understanding, and attitudes, needed to develop SPS conceptual understanding of them (SPS) and context are equally important (Molefe & Aubin, 2021). SPS, within the context of the Nigerian science curriculum, became the primary focus for this study. These skills can help students understand biological concepts better. As highlighted by Ajanigo and Aboritoli (2021), developing SPS is essential for fostering an extensive comprehension of scientific concepts and this stands as one of the most pivotal objectives within the realm of Science, Technology, Engineering, and Mathematics education.

5.2.1 Pre-service Teachers' Conceptual Understanding of Science Process Skills

The open-ended questionnaire on conceptual understanding of SPS entailed nine skills - *classifying, measuring, operational definition, identifying and controlling variables, experimenting, hypothesising,* and *predicting* - which were selected from the ones stipulated in the Nigerian science curricula. The pre-service teachers were asked to explain/define the skills in their own words (see Appendix E). It should be noted that in qualitative research, researchers can use enumeration and statistical analyses (Dey, 2003). Thus, the results of this subsection contain numerical data presented in both text and tabular formats.

Table 5.1 shows the frequencies of the test scores concerning the 24 pre-service teachers' (participants) conceptual understanding of the aforementioned SPS. The test results were categorised into either **Could define (CD)** for the participants that defined the skills correctly and **Could not define (CND)** for those that did not give correct definitions for the skills. The completed questionnaires were marked and scored by matching the participants' responses with the SPS definitions by selected authors (see Chapter 2, Table 2.2). Those that were categorised as CD included key-terms found in the definitions in their responses and those that were assigned CND either gave definitions that were irrelevant to the skill or did not include key terms in the scholarly definitions. Samples of the participant's responses to the questionnaire concerning definitions of each of the skills were presented verbatim.

Table 5.1

Frequency Table for Pre-service Teachers' Conceptual Understanding of Science Process Skills

Science Process Skills	Frequencies	
	CD	CND
Classifying	16	8
Measuring	5	19
Operational definition	0	24
Identifying and controlling variable	1	23
Experimenting	5	19
Hypothesising	2	22
Predicting	5	19
Identifying	2	22
Observing	0	24

Note: CD - Could define; CND - Could not define

5.2.1.1 Classifying

Analysis of the questionnaire showed that the majority (16) of the participants defined the skill correctly. It should be noted that, in this research study, the participant's understanding of the nine SPS was equated to their ability to define them. It is acknowledged that there are many definitions of *classifying* in the literature. Nevertheless, in this case, their conceptual understanding of classifying was examined in comparison with definitions by Idiege et al. (2017) and Charlesworth and Lind (2010). The definitions by these authors were selected because they were explicitly stated and had elements of what I was looking for (e.g., grouping phenomena based on similar/different features as in plant taxonomy). Below are a few correct definitions provided by some of the participants concerning the skill:

"This deals with the grouping of things either due to the criterion or similarities they share in common.'' (Participant 8)

"This is the process of separating/setting aside things based on the difference in their certain features.'' (Participant 4)

"This is the grouping or ordering of science objects and events according to an established scheme.'' (Participant 12)

On the other hand, a few participants (8) could not give a suitable definition of the skill. Analysis of the questionnaire suggested that they thought "Classifying means to be able to classify or differentiate things'' Participant 17) or "Classifying means division" Participant 22). An irrelevant definition included "Science process skills are the fact of learning or having knowledge about something'' (Participant 1).

The overall responses of the participants suggest that the majority of them had a good conceptual understanding of this skill. The implication is that pre-service teachers studying plant taxonomy may have a basic understanding of *classifying*.

5.2.1.2 Measuring

The pre-service teachers' (participants) understanding of this skill was based on how they were able to state key terms from the definitions provided by Ediyanto et al. (2017) and Zeidan and Jayosi (2015). The definitions provided by these authors were compared with the responses given by the participants because they (the authors) defined the skill using more scientific terms rather than just giving a regular definition of the skill.

Analysis of the questionnaire revealed that very few (5) participants defined the skill correctly while the majority (19) of them gave wrong explanations. Below are a few correct definitions that were given by the participants:

"It means using both standard and non-standard measures to estimate the dimension of an object." (Participant 23).

"Measuring means using both standard and non-standard measures to estimate the dimension of a science object." (Participant 12).

"It is a process of determining the size, length and weight of an object quantitatively.'' (Participant 14).

The wrong definitions given by most of the participants lacked the right key features in those provided by the authors, as evident in the definitions below:

"This means to weigh something with another.'' (Participant 20).

"It involves the measuring of research data.'' (Participant 6).

"Measuring is taking note of the level of a thing or object attained.'' (Participant 2)

Analysis of the responses of the participants concerning measuring suggested that most of them lacked conceptual understanding of it. The implication of this was that the pre-service teachers may have a challenge in using the skill to understand concepts related to plant taxonomy.

5.2.1.3 Operational Definition

Analysis of the questionnaire on this skill showed that all (24) of the pre-service teachers gave wrong definitions of the skill. Similar to the previous SPS, the pre-service teachers' understanding of this skill was rooted in their ability to give definitions tailored to or similar to those given by Ediyanto et al. (2017) and Idiege et al. (2017).

In relation to the wrong definitions of the skill, the participants' responses included: *"definition of professional terms''* (Participant 2), *"giving meanings to certain phenomena, objects or events''* (Participant 16*), "this is known as the definition of terms''* (Participant 19) *and "this is the process of giving full details of the word, and objects,* etc'' (Participant 4).

While most of the participants did not define the skill correctly, a few of them stated that they had "no idea" on the questionnaire. The findings suggest that the participants did not have a conceptual understanding of operational definition. The implication was that pre-service teachers may find the skill very abstract and difficult to develop within the context of plant taxonomy.

5.2.1.4 Identifying and Controlling Variables

Table 5.1 shows that only one of the pre-service teachers provided a correct definition of the skill, that is, *"the ability to know what variable is available and using the variable to affect another variable"* (Participant 2). The rest (23) gave wrong definitions. Some of them stated that they did not have an idea about the skill. An analysis of the questionnaire showed that their wrong definitions did not correspond to the ones given by Zeidan, and Jayosi (2015) and Idiege et al. (2017). Below are a few definitions given by the participants on this skill:

> "This means to control and be able to identify variables in science process skills.'' (Participant 23).
>
> "Ability to identify a problem in science.'' (Participant 1).
>
> "This is the process whereby a variable is present in an experiment and it can easily be identified and controlled." (Participant 7).

Similar to the operational definition, the findings explain that this is an integrated SPS hence its abstract nature. The implication is that these pre-service teachers may find it challenging to use this skill in understanding biological concepts based on plant taxonomy.

5.2.1.5 Experimenting

Although experimenting is considered a generic skill (Molefe & Aubin, 2021), it is stipulated as a SPS in the Nigerian science curriculum (FRN, 2013). Analysis of the questionnaire showed that only five participants could provide aspects of this skill that were similar to those found in Zeidan and Jayosi (2015) such as "testing a hypothesis, gathering data and asking questions".

Table 5.1 shows that a few participants (5) possessed an understanding of experimenting because they were able to define the skill correctly. The majority (19) of them gave wrong definitions for the skill. Below are some of the correct responses given by the participants on this skill:

> "It is the process of designing data-gathering procedures as well as the process of gathering data for testing hypothesis." (Participant 6).
>
> "Experimenting is being able to conduct an experiment, including asking an appropriate question, stating a hypothesis, identifying and controlling variables.'' (Participant 12).
>
> "It is the process that involves testing the validity of hypothesis drawn and it also involves interpretation of data and drawing conclusions from it." (Participant 4).

Below are some of the wrong responses given by the pre-service teachers:

> "It is the process of being in contact with the data gathered or practical aspect''
>
> (Participant 13).
>
> "A test under continual conditions'' (Participant 3).
>
> "Experimenting means to carry out an experiment'' (Participant 20).

Analysis of the responses provided by pre-service teachers indicates that a significant portion of them demonstrate a lack of conceptual understanding regarding experimentation. This observation may imply that they have had limited exposure to practical activities. The implication here is that the majority of the pre-service teachers might find the skill challenging to use in understanding plant taxonomy-based concepts. After all, in plant taxonomy, several concepts are developed through practical work, which entails experimenting.

5.2.1.6 Hypothesising

Analysis of the questionnaire revealed that only two pre-service teachers were able to correctly define hypothesising. The basis for their understanding of this skill was in relation to stating basic terms such as stating the proposed solutions for experiments and providing a preliminary response to a problem or a guess as purported by Ediyanto et al. (2017) and Idiege et al. (2017).

For Participant 14, hypothesising "is the process of raising questions in the form of argument for it to be tested whether it is true or not''. On the other hand, Participant 19 defined the skill as "a proposed explanation made before the start of an investigation". The responses of these two participants were the only definitions that were close to those given by the authors. The majority (22) of the participants showed poor conceptual understanding of the skill. Below is a non-committal response and two of the many wrong definitions that were given by the participants:

> "No idea.'' (Participant 1).
>
> "Hypotheses are intelligent guesses.'' (Participant 15).
>
> "Hypothesising suggests an explanation consistent with available observations, questions and evidence. When one makes hypotheses, he links information from experiences that may explain both how and why events occur." (Participant 12).

Analysis of the overall responses on this skill suggests that the pre-service teachers do not have a conceptual understanding of the skill since they could not give definitions close to the ones provided by Idiege et al. (2017) and Ediyanto et al. (2017). The implication is that these pre-service teachers may not be able to construct knowledge, find answers to their own questions and be able to test out theories related to plant taxonomy.

5.2.1.7 Predicting

Pre-service teachers' understanding of this skill was based on how they were able to define it correctly in relation to the definitions by Chiappetta (2014) and Idiege, et al. (2017). For Chiappetta (2014), predicting involves stating the outcome of a future event based on a pattern of evidence, experience, or observations. Idiege, et al. (2017) defined predicting as making educated guesses about the outcomes of future events.

Analysis of the questionnaire showed that only five of the pre-service teachers' responses (definitions/explanations) concerning the skill were correct. Below are some of the correct responses:

> "This is the formulation of an expected result based on experience.'' (Participant 13).
>
> "Ability to forecast or give an estimation about future events.'' (Participant 1).
>
> "The skill of predicting involves forecasting what is believed will occur in the future." (Participant 12).

The definitions given by the participants concerning the skill appeared to involve forecasting events based on observations and previous experiences.

On the other hand, most (19) pre-service teachers gave the wrong definitions of the skill. Below are some of the participants who failed to recognise predicting as a science process skill. They appeared to equate it with making guesses or everyday predictions. Below are how some of them defined the skill:

> "This involves the guessing of a particular thing but not compulsory correct.'' (Participant 8).
>
> "Predicting means to predict something.'' (Participant 17).
>
> "It's like what is going to happen? If I do this, this will happen. How will we find out what will happen? What are we going to do to find out what happens?" (Participant 21).

Analysis of the questionnaire suggests that the majority of the pre-service teachers might have a challenge concerning conceptual understanding of the skill. The implication is that the teachers might need to practice these skills to successfully develop and execute them in plant taxonomy.

5.2.1.8 Interpreting Data

The results of the analysis of the questionnaire showed the same pattern as hypothesising-based performance on defining SPS. Only two pre-service teachers could provide appropriate definitions that entailed, for instance, "making inferences" and "data processing" (Shahali et al., 2017). For instance, Participant 2 defined interpreting data as *"making inferences from collected data"* while Participant 19 stated the skill *as "an explanation involved in data processing''.*

On the other hand, twenty-two pre-service teachers could not provide correct definitions of the skill. They gave definitions that do not bear similar key features to the definitions given by Shahali et al. (2017)). For example, in defining interpreting data, they provided the following definitions: "*Interpreting data requires other science process skills''* (Participant 5), *"making analysis of the experiment about to be done''* (Participant 24). It was interesting that one participant (Participant 12) had "*no idea''* about what the skill of interpreting data is all about.

The result suggests that the majority of the pre-service teachers who participated in this study lacked a conceptual understanding of interpreting data. The implication is that pre-service teachers might not be able to interpret data related to plant taxonomy.

5.2.1.9 Observing

Table 5.1 shows that all the twenty-four pre-service teachers were unable to provide a suitable definition of this skill. In this study, the expected definitions were supposed to be similar to those of Miles (2010) and Zeidan and Jayosi (2015), which had a phrase - "using the five senses for noting the properties of objects".

Below are some of the responses given by the participants.

"This is making a conclusion over an experiment that is carried out.'' (Participant 24).

"It involves the recording of research data in a suitable manner.'' (Participant 5).

"Observing means to take note." (Participant 22).

Analysis of the questionnaire suggests that the pre-service teachers who participated in this study lacked a conceptual understanding of the skill. The implication is that the pre-service teachers, while teachers might be able to observe phenomena related to plant taxonomy, might not denote that they understand what observing is (conceptually).

5.2.2 Pre-service teachers' performance on science process skills

This section presents the findings concerning the science process skill (SPS) test. The purpose of the test and the questionnaire evidence was to establish whether there was complementary and/or supplementary information concerning the teachers' SPS. The SPS test used in this study was composed of nine items addressing each of the SPS selected (see Table 5.1). The details of the contents of the test are presented in Chapter Four (also see Appendix G).

Figure 5.1 shows the performance of both third and fourth-years pre-service teachers concerning the selected SPS namely: *classifying, measuring, operational definition, identifying and controlling variables, experimenting, hypothesising, predicting, interpreting data and observing.* It should be noted that the passing mark for the test was 50%.

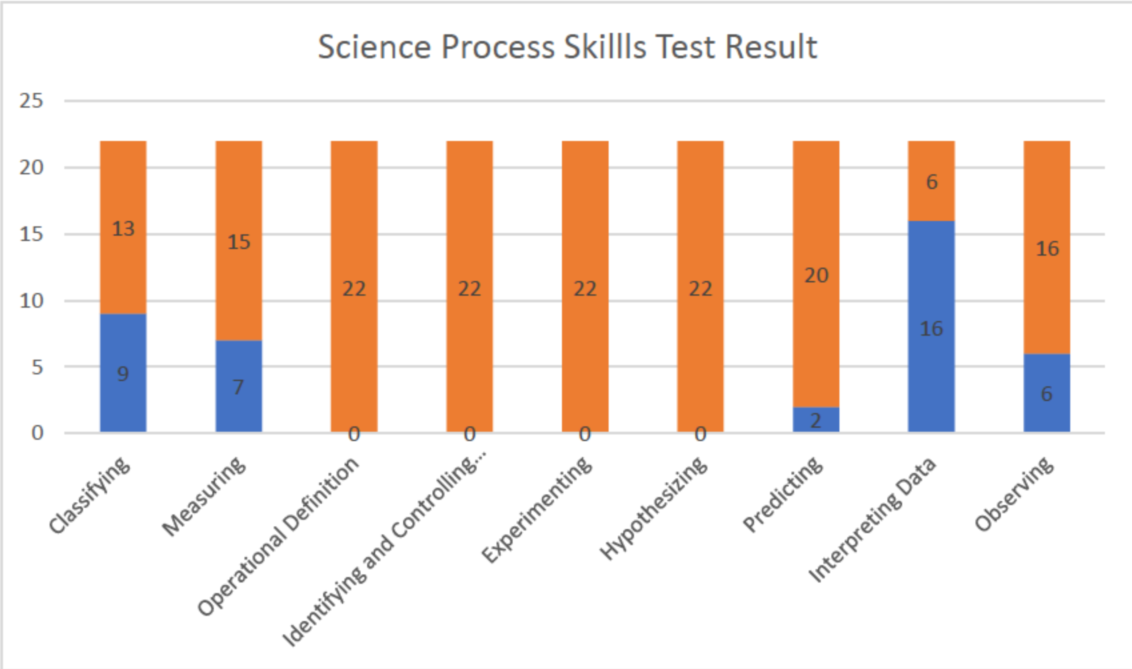
5.2.2.1 Classifying.

Figure 5.1 shows that less than half of the pre-service teachers (9) managed to score over 50% of the total mark (i.e., 12 marks). It is necessary to compare the results from the analysis of this test with those of the questionnaire on conceptual understanding. The findings from the test are in contrast with the results of the open-ended questionnaire on conceptual understanding of the same skill in which the majority (16) of the participants defined the skill correctly.

The contrasting findings suggest that, although most of the pre-service teachers had a basic understanding of *classifying*, they had not yet developed an understanding of the associated plant taxonomy-based concept tested (this was explored further in Section 5.3). The implication is that pre-service teachers need to understand plant taxonomy-based concepts and have an appropriate level of biological literacy first before they can be developed further through SPS. The majority of the pre-service teachers had a conceptual understanding of the skill in which they could classify phenomena related to plant taxonomy that can be challenging when using branched keys in plant taxonomy.

Figure 5.1

Pre-service Teachers' Performance on the Science Process Skills Test



Note: Total Pass

Total Fail

5.2.2.2 Measuring

The SPS test included *measuring*. Analysis of the test scores showed that only seven of the teachers managed to receive a passing grade concerning the skill while the majority (15) failed the test. The finding is similar to the results of the analysis on conceptual understanding of the skill (*measuring*) where a larger group (19) of the pre-service teachers had no conceptual understanding of the SPS (see Table 5.1).

This result suggests that the majority of the pre-service teachers have not yet developed the skill for understanding plant taxonomy. The implication is that pre-service teachers need to develop this skill and the associated taxonomy-based biological concepts for them to understand plant taxonomy, as the skill appears to be challenging for the pre-service teachers.

5.2.2.3 Operational Definition

The analysis of the result as seen in Figure 5.1 shows that none of the pre-service teachers scored a pass mark on the test. A total of 21 pre-service teachers who were in their third and fourth years scored zero on this skill. Only one of them managed to get a score of 5, which is still below the passing threshold. This indicates that all (22) of the pre-service teachers have not yet developed this skill which is necessary for understanding plant taxonomy.

The same dismal performance was realised in the findings of the open questionnaire (see 5.2.1.3) that assessed respondents' understanding of the operational definition. The results of the analysis of the questionnaire revealed that all (24) of the pre-service teachers defined the skill incorrectly; not one of them provided a description that accurately described the skill. This reveals a lot about the state of conceptual understanding and the development of operational definitions among pre-service teachers. This suggests that if the pre-service teachers lack conceptual understanding of the skill, this may also affect their performance on the same skill. The implication is that if pre-service teachers find it difficult to develop the skill for understanding plant taxonomy, it will be evident in their performance of the skill within the context of plant taxonomy.

5.2.2.4 Identifying and Controlling Variables

Analysis of the test as shown in Figure 5.1 revealed that none of the pre-service teachers who took the test evaluating their ability to identify and control variables obtained a good score. All the 22 pre-service teachers scored zero on the test. The significance of this is that all the pre-service teachers have not yet developed this skill for understanding plant taxonomy. This suggests that the teachers have not yet developed identifying and controlling variables for understanding plant taxonomy. The implication here is that the pre-service teachers need to develop an understanding of the components of the skill (e.g., dependent, and independent variables, and how to make results credible), particularly within the context of plant taxonomy.

Comparatively, in the results of the analysis of the open-ended questionnaire on conceptual understanding of this skill, just one of the pre-service teachers gave a correct definition of the skill, while others (23) gave wrong definitions. Because of this, the outcomes are quite comparable as the pre-service teachers all scored zero on the test and almost all of them had no conceptual understanding of the skill. This suggests that they have not yet developed identifying and controlling variables skills for understanding plant taxonomy.

The implication here is that the pre-service teachers may find the terms involved in this skill to be difficult which will affect their performance in plant taxonomy using this skill. This could be a result of their poor understanding of the skill since they cannot develop a skill, they do not have an idea of.

5.2.2.5 Experimenting

The results that were obtained from analysing the test showed that none of the pre-service teachers passed the test on this skill. The findings are similar to those that were obtained from the analysis of the test on the operational definition and identifying and controlling variables where all the pre-service teachers also scored zero in the test.

The result of this test is similar to the findings obtained from analysing the questionnaire on this particular skill where the majority of the pre-service teachers had no conceptual understanding of the skill. This suggests that these pre-service teachers did not have a conceptual understanding of experimenting and they had not developed the skill for understanding plant taxonomy. A lack of understanding of the skill may have resulted in a lack of development of the skill. The implication is that a lack of conceptual understanding of the skill may be the reason they had not yet developed the skill for understanding plant taxonomy due to their low performance in the test.

5.2.2.6 Hypothesising

The purpose of the question for this section was to determine whether or not the pre-service teachers had developed the skill of hypothesising, which is necessary for understanding plant taxonomy. The analysis of the questionnaire showed that none of the pre-service teachers, both in their third and fourth years, have developed this skill because they all scored zero on the test given to them.

In a similar vein, according to the results of the analysis of the open-ended questionnaire, only one pre-service teacher out of the total respondents provided an accurate explanation of the skill while others (23) had no conceptual understanding of the skill. In each of these scenarios, it is reasonable to conclude that the pre-service teachers have not developed this skill for understanding plant taxonomy. The implication is that the pre-service teachers were unable to use the knowledge of this skill to state the hypothesis that was in the plant taxonomy exercise and this could be due to their lack of knowledge of the skill.

5.2.2.7 Predicting

Analysis of the test on this skill showed that only two of the pre-service teachers passed the test while twenty of them failed the test by scoring points lower than the minimum required mark to pass the test. Therefore, as shown in Figure 5.1, the overall number of pre-service teachers who developed the skill for understanding biological concepts based on plant taxonomy is relatively very low.

Comparatively, the analysis of the open-ended questionnaire on conceptual understanding of predicting (see. Chapter five, 5.2.1.7) revealed that almost all the pre-service teachers (19) had no conceptual understanding of the skill while only a few (5) of them provided proper definitions/explanations for the skill. This suggests that the majority of the pre-service teachers have not developed this skill for understanding plant taxonomy and also lack conceptual understanding of the skill. The implication is that a lack of conceptual understanding of this skill could have resulted in the pre-service teachers not being able to predict what would happen in the experiment given in the test on this skill.

5.2.2.8 Interpreting Data

Analysis of the test on this skill indicated that a total of 16 pre-service teachers achieved at least a pass grade of 50% for this aspect of the test while only a few (6) of the 6 pre-service teachers failed the test. The conclusion that can be drawn from this finding is that the number of pre-service teachers who are well-developed in interpreting data for understanding plant taxonomy is quite high.

This result is very different from the result of the analysis of the open-ended questionnaire on conceptual understanding, which showed that only two pre-service teachers had conceptual knowledge of the skill, while the majority (22) of them were unable to give an accurate definition of the skill. These results, when compared with each other, are very surprising because they showed that even though pre-service teachers do not have conceptual knowledge of this skill, they passed the SPS test.

This suggests that the majority of the pre-service teachers had developed the skill for understanding plant taxonomy as seen in their performance (Figure 5.1). The implication of most of the pre-service teachers having a low conceptual understanding of interpreting data but a high level of performance in the test may be that they were unable to define the skill using scientific terms related to that of the authors used but found the test on the skill to be quite easy. The test on the skill involved them interpreting data represented in a figure.

5.2.2.9 Observation

The number of pre-service teachers who failed the test for this skill is higher than those who passed the test as seen from the analysis of the test shown in Figure 5.1. A total of 16 pre-service teachers did not get a pass mark of 50% thereby failing the test on observation while six of them got a pass mark of over 50%. This implies that the number of pre-service teachers who have developed this skill for understanding plant taxonomy is very low. However, the analysis of the open-ended questionnaire showed that all 24 pre-service teachers gave incorrect definitions of the skill meaning that none of them explained/defined the skill correctly.

The finding suggests that the majority of the pre-service teachers had not developed this skill for understanding plant taxonomy with their low conceptual understanding of the skill. The implication is that the pre-service teachers' lack of conceptual understanding of this skill may be why they found it difficult to use the dichotomous key in plant taxonomy which resulted in their low performance on the test.

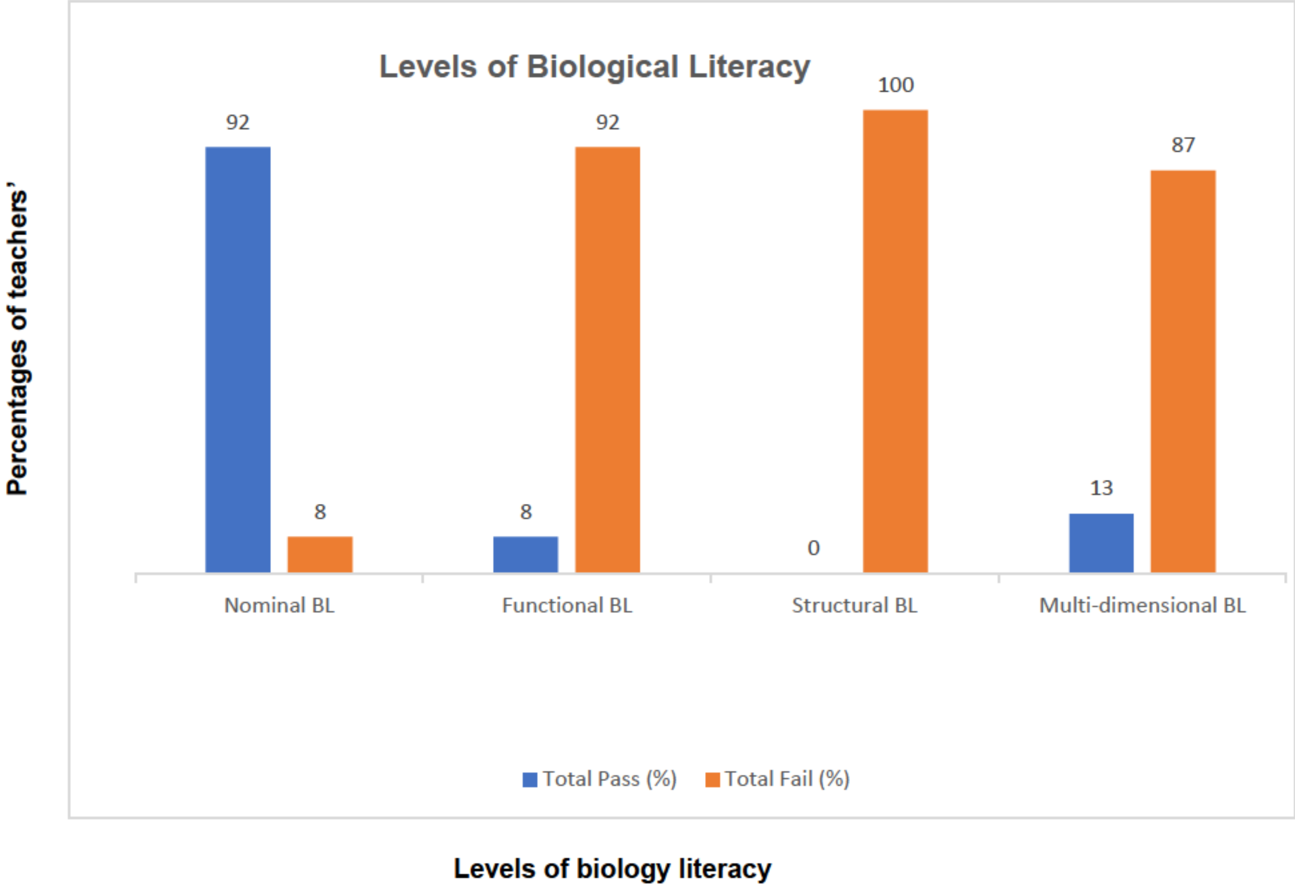
5.3 Pre-service Teachers' Biological Literacy

In this research study, the present pre-service teachers' level of biological literacy needed to be assessed as well. The results of the assessment were used to determine the influence of the level of the teachers' biological literacy in tandem with the use of SPS. It was also necessary to evaluate their levels of biological literacy in order to ascertain whether they are individuals who can critically analyse biological information, make informed decisions and actively participate in the scientific community. To assess the present pre-service teachers' levels of biological literacy, an open-ended questionnaire comprising questions tailored to them (the levels) was administered to the teachers (see Appendix H). The analyses of the data generated from the questionnaires on the levels are explained in this section.

I adopted the biological literacy framework in this study because it was important to know what level of biological literacy the pre-service teachers belong to. Uno and Bybee (1994) succinctly outlined all four levels of biological literacy (see Table 3.2).

Figure 5.2

Third and Fourth-years Pre-service Teachers' Levels of Biological Literacy



5.3.1 Nominal Biological Literacy

Students at this level (the nominal biology literacy) are expected to be able to identify biological terms or concepts. However, it should be noted that the students may also have misconceptions about such biological concepts and provide naive explanations of them. In this case, the pre-service teachers were expected to not only identify a biological concept – *taxonomy* – but also provide the meaning of it. Analysis of the questionnaire showed that, out of the 24 teachers who took a test concerning this level, a considerable number of them (22; 92%) could define taxonomy correctly. Only two teachers (8%) were not able to define plant taxonomy correctly (see Figure 6). Below are a few of the correct definitions given by the pre-service teachers:

> "Plant taxonomy can be defined as the process of giving names to plants. It also means systematically naming plants based on shared common characters and similarities." (Participant 4).
>
> "Plant taxonomy can be defined as the naming, identifying and classification of plants into different species." (Participant14).
>
> "Plant taxonomy is the systematic grouping, classifying and naming of plant species based on common characteristics." (Participant 22).

The findings suggest that the majority of the present teachers do not have challenges with the understanding of key biological concepts such as taxonomy. Their assimilation of biological concepts (e.g., taxonomy) might have been immediate because they heard about them and are also familiar with plant taxonomy. That said, in *taxonomy* – the branch of biology – scientists, for instance, <u>*classify*</u> species into taxonomic units of increasing breadth. It was interesting that most teachers were not conceptually challenged with regards to taxonomy. Firstly, definitions of biological concepts such as taxonomy are found in textbooks, biology course materials and/or assessment materials. Secondly, their conceptual understanding of SPS – *classifying* – was also better (see Table 5.1).

5.3.2 Functional Biological Literacy

In this case, the students are expected to define certain biological terms. However, the challenge at this level is memorisation and limited understanding of such terms or concepts (Uno & Bybee, 1994, p. 554.). In the present study, the pre-service teachers' level of biological literacy was assessed according to their understanding of the concept *bioremediation* in relation to bacteria, and most importantly, its use. Analysis of the questionnaire responses showed that a significant number of the teachers (22; 92%) were not able to select a statement that connected bioremediation to bacteria and reduction of pollution while 2 (8%) could do so.

The findings suggest that the majority of the pre-service teachers do not possess this level of biological literacy. Furthermore, the teachers might have not been able to relate bioremediation from the classification of organisms, which entails domain bacteria, and prokaryotes and their uses in research and technology to plant taxonomy.

5.3.3 Structural Biological Literacy

Students are required on this level to understand conceptual diagrams of biology and possess procedural knowledge and skills of biology. Here, the pre-service teachers were required to *construct a dichotomous key* by classifying plants into seedless and seed-bearing plants using the diagram provided. Analysis of the data on structural biological literacy level shown in Figure 6 revealed that all the 24 pre-service teachers who took part in this study scored zero (100%) none of them passed the test. The findings suggest that none of the pre-service teachers belong to this level of biological literacy since none of them could deal with conceptual diagrams of biology and organise biological concepts in their own words. The reason for this result might be because biology as a subject tends to have a whole diagram in most of its topics and students might find this discouraging and a bit cumbersome, since understanding biological diagrams requires students to master biological concepts and be able to link them together scientifically.

5.3.4 Multi-dimensional Biological Literacy

In this case, students need to understand the place of biology among other disciplines and society. They should be able to relate biology topics to other topics and disciplines. On the multi-dimensional biological literacy level, the analysis of the data showed that three of the pre-service teachers (13%) passed while 21 of them (87%) failed the test. This simply suggests that the majority of the pre-service teachers do not belong to this level of biological literacy.

The inability of the pre-service teachers to relate biology to other disciplines might be because they lack the necessary opportunities that require them to link their knowledge of biology to their social life and other disciplines in science. Also, it might be due to the use of traditional teaching methods by teachers which focus mainly on transferring scientific knowledge without linking them to the students' everyday life. A lack of interest in practicals among students has deprived most of them of applying the scientific knowledge they can acquire during practical activities in their everyday lives and other scientific disciplines.

There is a relationship between SPS and biological literacy in the sense that these skills are essential abilities that students need to master to help them learn biology. SPS promotes rational thinking in students, and it leads to an increase in scientific literacy (Chandran & Vitus, 2020). It is believed that the knowledge of SPS will help students perform well in biology. That is why it was necessary to determine the pre-service teachers' level of biological literacy and attain insights on these skills (SPS) in tandem with the levels.

5.4 Pre-service Teachers' Use of Science Process Skills to Understand Plant Taxonomy Based Biological Concepts

In this section, I presented an overview of the cogenerative dialogues (Cogen) done with the participants. Cogen formed the basis for information concerning the present pre-service teachers' use of science process skills (SPS) to understand plant taxonomy and the factors that influenced the use of these skills. It should be noted that Cogen, by nature, could be viewed as the "social process dependent on the cooperation of the participants who themselves engage in particular activities…", hence an *activity system* (Stith & Roth, 2006, para. 18). Thus, a framework was needed that could provide an additional complementary and/or supplementary information by virtue of its ability to not only explicitly show connections among *activity-actions-operations* but also how *meaning* is affected. Thus, the *Cultural-Historical Activity Theory* (CHAT) analytical framework, which comprised data generated from the pre-service teachers' focus group interview, proved useful in this case. Data from CHAT and Cogen provided answers for the research questions (RQ) below:

RQ2: How did pre-service teachers use SPS to understand biological concepts based on plant taxonomy?
RQ3: Which factors influenced pre-service teachers' use of SPS to understand biological concepts based on plant taxonomy?

The associated framework in this section is CHAT and it was important to adopt this because it encourages humans to learn collectively by interacting within the six levels of activity theory (subjects, tools, objects, community, rules and division of labour) (Engestro¨m, 1999). In addition, CHAT is a theoretical framework that can be used to better understand practice in complex learning environments where numerous individuals engage in collaborative activities within a single organisation or across multiple organisations (Yamagata-Lash (2010). To understand how SPS are being developed, practised, and situated within social and cultural contexts, it was important to use CHAT.

5.4.1 Overview of Cogenerative Dialogues

A small group cogenerative dialogues was employed in the present study, where students were asked to express their thoughts and ideas after the plant taxonomy lesson in which the lecturer taught plant taxonomy-based subtopics - taxonomy and systematics, the significance of plant taxonomy, and a list of plant taxonomic systems (see Table 5.1). Despite the subject being previously taught, the lecturer expected active student engagement. However, all students remained quiet, appearing familiar with the topic as the lecturer spoke.

Tobin and Roth (2005) state that during Cogens, shared experiences among participants are evaluated by reflecting on the teaching-learning activities, concentrating not just on one participant but all of them. They can also be viewed as sessions where a teacher and a small group of students discuss data from a previous class and come to a consensus on new rules for the class or adjustments to teacher and student roles. Table 5.1 shows how the Cogens unfolded during the present study. It should be noted that after about 30 minutes of instructions, I led the pre-service teachers in a Cogens to wrap up the course. According to Siry (2011), cogenerative dialogue (Cogen) promotes the ideals of respect, equity and variety. Respect entails listening to what others have to say and using appropriate language to express oneself without offending others. Equity entails taking turns speaking and encouraging the more reserved members of the group to speak more. Diversity entails supporting various viewpoints and appreciating individual differences.

Cogens have been employed in urban education for many years and were shown to be an effective technique for assisting students in having discussions with teachers and researchers that accurately reflect their perspectives and enhance their learning of science (Pei-Ling, 2021). She added that to identify major issues in scientific teaching and learning, Cogens can be held routinely (e.g., once per week) during a semester with students, instructors, researchers, and administrators. Cogens may also improve students' academic performance, attendance, and general well-being in the classroom (Tobin, 2010). Cogens involve individuals listening to one another's worries and coming up with workable solutions as a group. Boss and Linder (2016) reported that through the process of Cogens, students feel more comfortable in sharing ideas for enhancing the learning environment and identifying the factors that impede their learning. It provides an avenue for students to connect and strategise with one another and their instructors on how to alleviate the pressures of these factors.

Table 5.2

Schedule of Cogenerative Dialogues that Took Place in the Research

Date	Type of Cogenerative Dialogue	Summary	Symbol
2nd March 2022	Small group cogenerative dialogue	The students reflected on the lesson taught on plant taxonomy. Then they shared ideas.	Cogen_I
3rd March 2022	Small group cogenerative dialogue	The students offered suggestions concerning feasible solutions to abstract content in plant taxonomy.	Cogen II

5.4.2 Making the Cogenerative Dialogues Authentic in this Research Study

In this study, authenticity criteria (see Guba & Lincoln, 1989) needed to be used to engage the pre-service teachers in the process of cogenerative dialogues (Cogens). According to Guba and Lincoln (1989), the authenticity criteria should entail ontology, educative, catalytic and tactical. Table 5.2 shows how each of the criteria helped shape the Cogens.

Table 5.3

Elements of the Research's Authenticity Criteria and the Associated Steps Used

Authenticity Criteria	Meaning	Step
Ontology	We all benefit from one another's knowledge.	Participants are invited from two different levels. Participation in the cogenerative dialogue was voluntary.
Educative	Take instruction from one another and learn something new.	Everyone is given a chance to speak, and no voice is given preference.
Catalytic	Should adopt a constructive change.	The goal of every cogenerative dialogue is to provide workable ideas and a strategy to enhance instruction and learning.
Tactical	Everyone is encouraged to take advantage of the research's findings.	We encouraged ourselves to individually make a contribution to enacting change and then follow up to evaluate how it went.

Prior to starting the Cogens, I offered a quick explanation of what it entails to the pre-service teachers and the lecturer. I encouraged the teachers to be open in their expressions and questions. I wanted to record the process on a video, but the lecturer advised otherwise, thus and I took notes during teaching and recorded dialogues with their consent, capturing images after the lecture.

The ontological phase in relation to this study meant inviting pre-service teachers in order to learn from them and this did not involve only one but different sets of teachers from two levels. Here, I had Cogens with them in order to identify problems or anything we found interesting during the lecture they had. Most of the teachers spoke about the problems they were able to identify during the lecture. Figure 5.3 shows the different groups of pre-service teachers who were invited to the Cogens.

The educative phase means that everyone involved in the dialogue needs to talk to each other and learn something new. I wanted to know what the pre-service teachers think about plant taxonomy and whether they had feedback about their lecturer's mode of teaching. Here the pre-service teachers spoke about the problems identified and how to provide solutions to these problems. Figure 5.4 shows the interaction between pre-service teachers learning from each other.

The pre-service teachers suggested solutions to the problems encountered during the teaching of plant taxonomy in order to make a change in teaching and learning (Catalytic Phase). This meant that for the lecturers to be catalytic, they needed to implement some of the solutions listed by the pre-service teachers while

teaching plant taxonomy. The tactical phase involved everyone doing their part in order to enact changes and follow up to see if it worked.

5.4.3 Results from the Cogenerative Dialogues

I wanted to know the pre-service teachers' perceptions of plant taxonomy as a difficult topic and the challenges they face in the topic during the cogenerative dialogue. The teachers actively shared why they did not like the topic in several conversations (Figure 5.5).

5.4.3.1 Problem Faced While Studying Plant Taxonomy

During the cogenerative dialogue, the pre-service teachers highlighted their struggles with plant taxonomy. Many found the *similarity of numerous plants* to familiar species challenging, hindering their ability to classify and understand them. As they shared their difficulties, others nodded in agreement. Even when encouraged to speak up, the participants admitted they faced the same issues. Disagreement among pre-service teachers arose as they discussed their dissatisfaction with lecturers' explanations of the subject. The concern over the *identification of plants* and teaching approaches emerged prominently in the initial dialogue session.

Their *lecturers' teaching style* also drew concern, with participants feeling that the vast scope of plant taxonomy required more effective teaching. They found the lecturer's abstract style challenging to comprehend. Despite plant taxonomy requiring practical experience, practical work is lacking, and teaching relies on abstract teaching. Some lecturers' *lack of subject knowledge* was also raised as an issue. The teachers' instructional methods hinder understanding, suggesting hands-on teaching for this complex subject.

5.4.3.2 Possible Solutions to the Teaching of Plant Taxonomy

Although the discussion focused on the learning challenges that pre-service teachers confront, it was important to discuss solutions in terms of plant taxonomy. The lecturers' techniques of instruction, which came up often in the dialogue, were the biggest obstacles for pre-service teachers to overcome when learning about plant taxonomy. There were recommendations made, such as using unconventional methods, educating slowly, and substituting practical tasks for abstract education. Given that some lecturers lacked prior teaching experience due to their scientific competence, some suggested that instructors with educational backgrounds should improve the way they teach. Below are some of the solutions suggested by the pre-service teachers:

> "Many of them have never attended education institutions. Since most of our lecturers are from science departments. Any lecturer teaching education courses should have an education postgraduate degree." (Participant12).
>
> "Despite the fact that in-service teachers are currently employed, there should be a way to train them" (Participant 7).

Some of the pre-service teachers suggested that the *lecturers improve their methods of instruction*, while others claimed that there should be suitable resources, such as tools and top-notch teaching materials that would make teaching plant taxonomy easy. One of the pre-service teachers proposed that *tools should be provided to lecturers* for exhibiting diagrams and pictures of diverse plants, particularly those that are similar to one another. Another one said that the school authority should *employ qualified teachers* because these lecturers are only working for the salary and they do not have passion for the job.

5.4.4 CHAT Analytical Framework: Responses from the Interview Questions

In this sub-section, I addressed CHAT components related to the present pre-service teachers' use of SPS to understand plant taxonomy-based biological concepts. Evidence from focus group interviews will be used to identify the themes (see Table 5.1), hence answering research questions two and three.

The focus group interviews comprised four groups (shown below). The groups were made up of six students. As referred to elsewhere, there were 24 pre-service teachers in their third and fourth years. The pre-service teachers in their third year were divided into two groups and the same was done for those in their fourth year.

The data from the focus group interview were separated using the following abbreviations:

Focus Group Interview 300 Level Group I: FG3I
Focus Group Interview 300 Level Group II: FG3II
Focus Group Interview 400 Level Group III: FG4III
Focus Group Interview 400 Level Group IV: FG4IV

5.4.4.1 CHAT-based Insights into the Teachers' Responses to the Interview Questions

Eight themes were elicited from the analysis of data generated from the pre-service teachers' responses concerning the use of SPS to understand plant taxonomy-based biological concepts. I used a manual method of analysing qualitative data to identify categories of information that constituted a given theme. That was used because it allowed me as the researcher to be flexible and adapt my approach as I immersed myself in the data and it also encouraged deeper understanding of the data generated. Maher et al. (2018) suggest that adopting manual data analysis that involves physically writing on sticky notes and using visual mapping techniques fosters

Table 5.4

Components of CHAT in Context and the Associated Focus Group Interview Questions

Component of CHAT	The component in this context	Matching questions/items (FGI schedule)
Subject	Pre-service teachers in relation to the use of science process skills (SPS) to understand biological concepts	1. Do you prefer learning about plant taxonomy by studying content only or using SPS? Explain why you prefer your choice.
Tools	Resources (e.g. textbooks, relevant and websites, etc.) available to the teachers and the pedagogy using SPS	1. What aspects of learning about plant taxonomy do you like and how has that hindered or improved your biology literacy or understanding of plant taxonomy? 2. Tell me what you think about studying plant taxonomy using SPS.
Rules	Rules (e.g., curriculum requirements, University rules and regulations, Cogen rule) about the use of SPS to understand biological concepts	1. Do you think your lecturers follow the rules concerning the teaching of plant taxonomy (e.g. curriculum requirements and the university rules concerning SPS)? 2. How much time do you spend studying biological concepts using SPS?
Community	Activities of pre-service teachers' community	1. Do you use SPS when learning plant taxonomy? 2. Tell me the reasons behind their use
Division of labour	Roles undertaken by the pre-service teachers in the use of SPS to understand biological concepts	1. Tell me what you use when using SPS to understand biological concepts better. 2. What do you use that (in 1.) for?
Object	Contextual factors that shape pre-service teachers' views concerning the use of SPS to understand biological concepts	1. Do you prefer using SPS in learning plant taxonomy? Please give reason(s) for your answer. 2. What difficulties do you have when using SPS to study plant taxonomy?

a deeper and more meaningful interaction with the data. In each theme, I selected examples of the teachers' responses in which they were expressive.

In relation to how the pre-service teachers used SPS to understand biological concepts based on plant taxonomy, the following themes were identified:

1. *The current pre-service teachers' preference for learning plant taxonomy (content or skills (including SPS).*
2. *The teachers' resources of interest and pedagogical approaches in plant taxonomy (resources & pedagogy).*
3. *Associated rules involved in the effective teaching of plant taxonomy; and time spent studying plant taxonomy using SPS (rules' application & duration).*
4. *Community use of SPS: Motives behind adopting and utilising SPS for learning plant taxonomy (communal use of SPS).*
5. *Skills used for understanding plant taxonomy.*
6. *Pre-service teachers' preference for using SPS for learning plant taxonomy (contextual influence in use of SPS)*

For the factors that influenced pre-service teachers' use of SPS to understand biological concepts based on plant taxonomy, a theme - *Difficulties faced by pre-service teachers in utilising SPS for plant taxonomy* - was identified.

5.4.4.2 The Current Pre-service Teachers' Preference for Learning Plant Taxonomy

When asked to share whether they preferred to learn about plant taxonomy by studying content only or by using SPS (Table 5.4; Subject), the teachers pointed to the latter (SPS). Their responses were based on *SPS, cognitive skills* (e.g., differentiating biological phenomena [e.g., plants]) and *knowledge*:

> **FG3I PST 1:** I would prefer our lecturers to use SPS because for us to know more, for example, we have observation as part of SPS so we have to observe different kinds of plants that we have so that we can differentiate them.
>
> **FG3II PST 3**: I prefer my lecturer to use SPS to teach me. Let us take for example Carica papaya tree and cashew tree if it is only theory, we will not be

able to differentiate between the two but when he uses SPS, we will be able to identify the structure, the type and the leaf thereby knowing the differences between the two trees.

The teachers' explanations also showed a connection between *SPS and easier learning experiences*:

FG4III PST1: I prefer using SPS because it makes learning easier. And apart from that it also makes learning about what we have been taught in class easier for us. Thank you.

FG4IV PST2: I prefer learning using SPS because plant taxonomy is not a course that should be taught abstractly. The use of SPS to teach the course will simplify the topic and make learning easier rather than teaching it abstractly.

For the teachers, *SPS* could also provide not only an opportunity for a *feel of phenomena* but also a key to *knowledge retention*:

FG4IV PST4: Yes, because it will enable the teacher to bring materials to the class that the students can interact with and this can be in the form of life plants or seeds. It is lively.

FG3I PST2: I like it when my lecturer uses SPS because there are times he comes to class with hibiscus flower and this enables us to have direct contact with the flower by observing it and we will be able to classify it under the group it belongs to.

FG4IV PST3: I prefer SPS because it brings the knowledge of what is being taught to real life.

FG4II PST 1: I prefer SPS because using SPS expose students more to the real world and help them to retain more knowledge.

FG3II PST1: Because in a class where we observe the plants, there's a way it sticks to our brain and we are able to remember it. Rather than just teaching us abstractly.

FG4III PST2: You tend to remember what you have been taught using SPS.

5.4.4.3 The Pre-service Teachers' Resources of Interest and Pedagogical Approaches in Plant Taxonomy.

In this case, the focus was on resources available to the pre-service teachers and the pedagogy using SPS. The teachers were further asked to provide aspects of learning about plant taxonomy that they liked and how that hindered or improved their biology literacy or understanding of plant taxonomy (Table 5.1; **Tools**). Their responses' were tailored to *SPS and/or biological resources* (e.g., Herbarium and gardens), and *issues related to biodiversity* (e.g., endangered species and conservation). For instance, **FG3I PST 2** said:

> "I like herbarium most and it has improved my understanding of SPS because this herbarium is a place where dried finely nice plant specimens are collected in large amounts where they are being stored for easy conservation. It helps to know the plants that are already endangered that are the plants that are going into extinction".

On the other hand, **FG31 PST 4** pointed out that she would go for "biological gardening because it makes us understand the different kinds of gardens that we have".

The pre-service teachers also responded that the *Nomenclature of plants* "is another aspect of plant taxonomy they like as this has played a crucial role in *improving their knowledge and understanding of plant taxonomy*. **FG3II PST2** noted that he liked "the aspect of giving names to plants as this has helped him to know some plants and their botanical names".

For **FG4III PST4,** the aspect of naming plants during practical is what he liked because "it has improved his biological understanding and learning by knowing biological names and nomenclature".

Three of the pre-service teachers also highlighted their preferred aspect of plant taxonomy which involves *scientific skills* such as SPS (e.g., classifying and observing), *field skills* (e.g., identifying plants) and *nomenclature* and *taxonomy-based knowledge.* This is evident in the excerpts below:

> **FG3II PST3:** I will say identification because when we are taught how to identify plants, it's so easier to see the plants outside and remember them and

identifying goes with naming as you cannot name a plant without identifying it first. So, it has improved my knowledge of plant taxonomy.

FG4IV PST1: The aspect I love most is classification because after identifying and naming, you need to classify them into their groups, phyla and families. That's why I love classification

FG4III PST1: The practical aspect as it helps to know the part of plant taxonomy you did not know before.

5.4.4.4 Associated Rules Involved in the Effective Teaching of Plant Taxonomy.

This theme was generated based on the sets of rules followed by the lecturers while teaching plant taxonomy. The pre-service teachers were asked whether they thought their lecturers followed certain rules and regulations (e.g., curriculum requirements and university rules) concerning the teaching of plant taxonomy (Table 5.1; **Rules**). The results showed mixed teachers' views.

Some of the pre-service teachers reported that their lecturers were *non-compliant with rules concerning SPS and/or curriculum* as stated in the responses below:

FGI 4III PST 2: In our school, they do not follow the university curriculum and SPS rules.

FGI 4III PST 4: In my opinion, they do not follow any rules. They do not follow the university rules because most lecturers are so lazy. There are no well-ventilated environments, and no good equipment, they just give you bulky materials to go and read**.**

FGI 4III PST 6: In my opinion, I don't think they follow the university rules and because the materials given to us are not well defined and too broad. For the SPS rules, practical are not well in place.

FGI 3II PST 4: They follow the university and curriculum rules because the curriculum is already in black and white. But, for SPS rules, they do not follow them.

The *Ineffectiveness of rule adherence* portrayed by the lectures was also mentioned by FGI 3II PST1 and FGI 4I PST6. **FGI 3II PST1** remarked that "their lecturers follow the rules but not in an entirely effective manner". On the other hand, **FGI 4I PST6** expressed a different perspective, stating that "lecturers do not adhere to university and the curriculum rules due to the broad and not well-defined materials given to them". He further stated that practicals are not well in place since they did not engage in any experiment as it was just theory all through.

On the other hand, the responses of some of the teachers suggested that their lecturers *implement the use of SPS* (e.g. identifying, classifying, observing and experimenting) in their *teaching approaches* (e.g., experimentation).

> **FG3I PST 5:** I will say, yes, he follows the university rules and SPS rules because he used identification skills when we went on a tour and he showed us different types of plants, their usefulness and their names.
>
> **FG3I PST 6:** They follow the SPS rules because our lecturer comes to class with flowers sometimes and classifies them to us and we observe the plants.
>
> **FG3I PST 2:** They follow/use the SPS, for example, the experimental skill; we are being subjected to practical after the theoretical class so we go on an experiment on different plants to know more about the plants and to know more about what we have been taught in class theoretically, so that's why I said they follow the SPS rules.

Furthermore, teachers' responses highlighted *partial compliance with the rules of SPS.* Their lecturers complied with one or two rules:

> **FGI 3II PST 3:** They follow the university rules, and curriculum rules but I don't think they follow SPS rules. For example, when we went on tour to a botanical garden we were too many and we couldn't understand or grab anything our lecturer was saying.
>
> **FGI 4III PST 3:** Some of them still follow the SPS rules in some aspects but not the curriculum rules.

5.4.4.5 Time Spent Studying Plant Taxonomy

The pre-service teachers were also asked about the time they spent studying plant taxonomy using SPS (Table 5.1 **Rules**). Some of the responses given by the teachers were tailored to *self-directed learning/self-study*. The majority of one of the fourth-year teachers' groups (**FGI 4III**) claimed that they spent a significant amount of time studying plant taxonomy on their own: "We go online to search for things on our own". **FGI 4II PST3** provided the basis for their claim: "We study plant taxonomy on our own because our lecturer does not really come to class".

Some pre-service teachers responded that they did not know of the time spent due to a lack of use of SPS to study plant taxonomy. Comments from two of the pre-service teachers are given below:

> **FGI 4I PST 5**: I am not sure of the time because I do not use SPS to learn plant taxonomy. The only method I use is just reading.
>
> **FGI 3II PST 2:** We do not use SPS but just content so I do not know how much time we spend.

5.4.4.6 Motives behind Adopting and Utilising SPS for Learning Plant Taxonomy

The emphasis here was on the activities carried out by pre-service teachers in learning plant taxonomy. The pre-service teachers were asked if they use SPS when learning plant taxonomy (Table 5.1 **Community**), and to state the reasons behind their use. The results showed mixed responses. For instance, the responses of some of the pre-service teachers did not only reflect the fact that they had a *lack of understanding of SPS*, but they also did not have *access to facilities*. For **FGI 3I** PST1, they did not use SPS for learning plant taxonomy mainly because of a lack of conceptual understanding of SPS: *"No because we do not have ideas of it. I mean we do not really understand what SPS are".*

Another pre-service teacher **FGI 4II PST 5** stated that "they do not have access to the necessary facilities and even some of the plants". This is why they do not use SPS to learn plant taxonomy.

In relation to the pre-service teachers who claimed to have an understanding of SPS, their responses were tailored to *cognitive skills development* (e.g., ability to differentiate and identify). Below are examples of the responses given by **FGI 3II PST 4** and **FGI 4III PST 4**:

> **FGI 3II PST 4:** Yes, I use SPS because after we have been taught in class, I'm going home to see some trees and leaves, and I will be able to state their structures according to what I have been taught. Like the day, we were given a flower, and on my way home, I saw another flower. I was able to differentiate between the flowers I saw and the ones they showed us in class.
>
> **FGI 4III PST 4:** Yes, because I use identification skills to identify some leaves that I use for cooking.

5.4.4.7 Skills Used for Understanding Plant Taxonomy.

In this case, the pre-service teachers were questioned about what they used while employing SPS to comprehend biological concepts (plant taxonomy) better. They were also expected to state what they mentioned it is used for (Table 5.1; **Division of Labour**). The teacher's responses pointed to the uses of SPS. These included *identifying, measuring, classifying and experimenting.*

In relation to using *identification skills* to understand plant taxonomy, **FGI 3II PST2** stated that she "used identification skills to identify some plants that are been taught to them in class at home and in her environment". **FGI 4III PST6** pointed out that he "uses identification skills to gain a better understanding of different aspects of plants such as identifying the names and botanical names of different plant specimens in the school".

> **FGI 4III PST 1** said she "uses measuring skills to measure the heights of plants" while **FGI 3I PST4** revealed that he "uses classification skills for grouping plants, leaves and flowers". For **FGI 3II PST 4, "**classification skills is the simplest of all the skills and that is why he prefers to use it for classifying different kinds of plants".

For pre-service teachers who claimed to have used *experimenting*, the basis for the skill was its connections with experimentation and/or practical activities. Below are a few responses given by the pre-service teachers:

FGI 4IV PST 4: Identification and experimental skills because picking the leaves to cook is an experimental procedure.

FGI 3I PST 1: I use experimenting skills because I always find practical activities fun.

5.4.4.8 Pre-service Teachers' Preference for Using SPS for Learning Plant Taxonomy.

It was important to gather information on the contextual factors that shaped the pre-service teachers' views concerning the use of SPS to understand biological concepts. In this case, the pre-service teachers were asked if they preferred using SPS in learning about plant taxonomy; they were expected to support their responses (Table 5.1 **Objects**). Some of the teachers preferred the use of SPS because they did not only give them a *better understanding* of the course, but also *aided both mastery and enhanced comprehension* of plant taxonomy. The teachers' responses were rooted in their (SPS) role in understanding course material, topical concepts and (knowledge) retention. The excerpts below are some of the responses given by the teachers:

FGI 3II PST 3: It will make us understand the course better. Because if you can see and observe, you will be able to understand.

FGI 3II PST 6: In addition, it is good to use SPS to understand a concept or a topic because it will aid mastery of the topic.

FGI 4III PST 2: I prefer to use the skill because it aids my retention.

FGI 4III PST 6: It helps you to comprehend

Preference for SPS was also linked with the ability to *engage in hands-on activities* and *motivation to do more research.* **FGI 4III PST1** gave a response that SPS involve practical methods (experimenting) which make learning adventurous thereby exposing them to more researchers and new experiences. For **FGI 4III PST 5**, SPS develop “student interest and motivates you to want to do more research about a particular plant”.

SPS were also preferred for learning plant taxonomy because they are at the heart of *interactive learning experiences* in plant taxonomy. They reported that most times when they are using SPS to learn plant taxonomy, they worked together in groups thereby interacting with each other:

> **FGI 3II PST 1:** It is interesting to use SPS to learn plant taxonomy since it involves all of us working together to classify plants.
>
> **FGI 3I PST 6**: It makes learning fun and interactive
>
> **FGI 4IV PST 5:** Yes, because it gives us the advantage of interacting with our colleagues and sharing ideas when we are in a group, for example, when you are working in a laboratory or when you go on tours to the botanical garden, forest and Herbarium.

5.4.4.9 Difficulties Faced by Pre-service Teachers in Utilizing SPS For Plant Taxonomy.

When the pre-service teachers were asked about the difficulties they encountered when using SPS to study plant taxonomy (Table 5.1 **Objects**), they pointed to a *lack of qualified lecturers* or *poor teaching approaches.* **FGI 4IV PST 1**, for instance, provided an example of the consequences of such approaches:

> **FGI 4IV PST 1:** The studying of plant taxonomy can be very stressful and the lecturers did not teach the topic properly, leading to us not having an interest in the topic.
>
> **FGI 4III PST 4**: The problem of lecturers dropping cumbersome materials for the topic instead of taking us through practical activities.
>
> **FGI 4IV PST 4**: Lack of qualified personnel to teach using SPS.

Another difficulty encountered by some of the teachers was the *problem with naming, comparing and identifying plants*. For **FGI 3I PST2**, "The course is very complex which makes it very difficult for us to start naming different trees because some trees have similar characteristics. The similarities of these trees lead to confusion in identifying and distinguishing between different plant species because some trees have similar characteristics."

FGI 3I PST6 and **FGI 3II PST1** also revealed that they found it hard to identify different plants and it got overwhelming sometimes as there were too many plants to identify.

Factors such as *financial constraints*, *inability to access a virtual laboratory* and *challenges in finding specific plants and/or leaves* were also reported by the teachers. For instance, **FGI 4IV PST 1** responded that *"one of the challenges is financial constraints and using this skill will make you travel and spend some money. Another one is the lack of devices (gadgets) for virtual laboratory".* **FGI 4IV PST 5** also pointed to the use of virtual laboratories (VL). For her, VL often required a stable internet connection which would need a considerable amount of data amid a poor network.

FGI 4III PST4 noted that their lecturers sometimes made use of complex leaves that were not readily accessible to them, making it challenging for them to work with these leaves. The responses of these pre-service teachers are given below respectively:

FGI 4III PST 3: Difficulties in finding some seasonal leaves.

FGI 3II PST 2: Difficulties in finding some plants that are not common.

FGI 4III PST 4: Lecturers making use of complex leaves (specimens that are not readily available).

5.5 Chapter Summary

This chapter detailed the presentation of result generated for the study. Data were obtained from pre-service teachers who participated in this study through open-ended questionnaires, focus group interview and cogenerative dialogues.

By providing answers to Research Question One: What are the pre-service teachers' conceptual knowledge of SPS and level of biological literacy? open ended questionnaires were used. The results showed that majority of the pre-service teachers do not have conceptual knowledge of SPS. in relation to their level of BL, the pre-service teachers belong to the nominal level of BL.

To answer research question two and three, focus group interview and cogenerative dialogues were used. Six themes emerged on how pre-service teachers use SPS to understand plant taxonomy. Some of the teachers noted that they use the SPS in identifying, classifying and measuring plants while others revealed that they do not have an idea of what SPS is hence, they do not use the skills in learning plant taxonomy.

The pre-service teachers revealed in focus group interview and the cogenerative dialogue several factors responsible for their use of SPS for understanding plant taxonomy. Teaching methods employed by their lecturers for teaching plant taxonomy was the major concerns of the teachers.

The next chapter will give a detailed discussion of the findings from the study through the lens of the theoretical framework of CHAT and BL.

Chapter Six: Discussion

6.1 Introduction

In this chapter, I presented the discussion on the results in Chapter 5. The results are discussed in line with the research questions of the study. These are restated below. Furthermore, the research design of the study and its gist are restated to highlight to its scope and context. The study is wrapped up with the responses to the research questions of the study, the frameworks of the study through the lens of the discussed results, knowledge contribution of the study, the limitations of the study, recommendations for further research and concluding comments are presented or restated.

The present research study sought to investigate how pre-service teachers utilise SPS to comprehend biological concepts, specifically focusing on plant taxonomy in a Nigerian University. The research questions for the study included:

1. What are the pre-service teachers'
   (a) conceptual knowledge of SPS?
   (b) Level of biology literacy?
2. How did pre-service teachers use SPS to understand biological concepts based on plant taxonomy?
3. Which factors influenced pre-service teachers' use of SPS to understand biological concepts based on plant taxonomy?

To answer these questions, the study employed a qualitative methodology. Using 24 pre-service teachers in their third and fourth years selected from a Nigerian University, the study tested pre-service teachers' conceptual knowledge of Science Process Skills through open-ended questionnaires that included a Biological Literacy data generation tool. This methodology was employed since it allowed for a comprehensive exploration of both qualitative aspects of pre-service teachers' conceptual understanding of SPS.

The study's methodological approach exhibited both strengths and potential areas for critical consideration. The incorporation of 24 pre-service teachers in their third and fourth years added a substantial participant base, contributing to the study's depth. The use of open-ended questionnaires provided a qualitative dimension to probe the intricate conceptual knowledge of SPS among participants. This qualitative approach allowed for rich data collection, offering a detailed exploration of participants' perspectives (Lester et al., 2020).

The choice of Focus Group Interviews (FGIs) for research questions 2 and 3 was well-justified for its capacity to elicit qualitative data. The open-ended nature of FGIs encouraged the participants to express their experiences, preferences and challenges authentically (Krueger & Casey, 2002). Yet, the effectiveness of FGIs hinges on the facilitator's skill in steering discussions and the participants' willingness to openly share their perspectives. This was made possible through cogenerative dialogue.

As referred to earlier, the focus of the study was on how the pre-service teachers use of SPS to understand biological concepts based on plant taxonomy in a Nigerian University". In science education, particularly concerning pre-service teachers, there exists a consensus that incorporating SPS is vital for a detailed understanding of biological concepts, specifically those rooted in plant taxonomy. The recognition of this significance is supported by the perspectives shared by pre-service teachers evidenced in their articulated preferences for utilising SPS in their learning experiences. Despite the acknowledged benefits of SPS, there are notable challenges faced by pre-service teachers in effectively integrating these skills into their understanding of plant taxonomy. These challenges underscore the need for targeted support and professional development opportunities for educators (Kubacka & D’Addio, 2020).

This study delved into the conceptual knowledge of SPS among pre-service teachers, explored how they employed SPS to comprehend biological concepts related to plant taxonomy, and identified factors that shaped their utilisation of SPS in this context. Additionally, the research sought to uncover any SPS developed by pre-service teachers themselves as part of their strategies for understanding biological concepts within the domain of plant taxonomy. By addressing these research questions, the study aimed to contribute valuable insights into the dynamics of SPS integration in the education of future biology teachers, shedding light on both the positive aspects and challenges associated with this pedagogical approach.

6.2 Responses to the Research Questions of the Study

This section provides the discussion of answers to the first research question. The section delved into an analysis of the pre-service teachers' conceptual understanding of specific Science Process Skills (SPS) and the level of biology literacy (BL). It aimed to assess the participants' conceptual grasp of various SPS, examining their ability to define and comprehend these skills and biological concepts.

The section further brought to the fore insights drawn from literacy about pre-service teachers and conceptual knowledge concerning SPS and BL. The analysis primarily focused on nine specific SPS: classifying, measuring, operational definition, identifying and controlling variables, experimenting, hypothesising, predicting, interpreting data, and observing. Each SPS was individually examined based on the participant's ability to provide accurate definitions.

In addressing Research Question 1—aimed at unravelling the conceptual knowledge of Science Process Skills (SPS) among pre-service teachers—the study engaged 24 participants in their third and fourth years. The chosen methods for data collection were open-ended questionnaires and a Biological Literacy Instrument, both of which adopted a qualitative approach. The application of open-ended questionnaires signified a deliberate effort to solicit comprehensive responses from pre-service teachers, allowing for a depth of insights into their perceptions, familiarity, and grasp of various facets of SPS. However, the efficacy of this method hinged on the quality of questions posed, the clarity of instructions, and the respondents' willingness to articulate their understanding.

Complementing this qualitative approach, the incorporation of a Biological Literacy Instrument further enhanced the depth of qualitative data collection. This instrument, adopting an open-ended format, enabled participants to express detailed perspectives on their biological literacy. Its potential limitations depended on potentially oversimplifying complex conceptual understanding and hypothetically missing the richness of qualitative responses.

6.2.1 What were the pre-service teachers' conceptual knowledge of science process skills and biology literacy in the context of plant taxonomy?

The study by Akinbobola and Afolabi (2010) revealed that pre-service teachers demonstrated a low level of conceptual knowledge of Science Process Skills. This deficiency in understanding had a direct impact on their ability to effectively teach these skills to students. Similarly, Kruea-In et al. (2015) found that pre-service teachers exhibited a moderate level of biological literacy, but their comprehension of Science Process Skills was limited. This suggests that while they may have a reasonable grasp of biological concepts, their understanding of the processes and skills related to scientific enquiry was not as strong. In line with these, Erkol and Ugulu (2014) discovered that pre-service teachers had a moderate level of understanding of Science Process Skills. However, their knowledge of these skills was deemed insufficient for effective teaching. This indicates that while they may have some familiarity with the skills, it was not at a level that would enable them to impart this knowledge effectively to their students. Molefe and Aubin (2021) investigated pre-service teachers' understanding of the scientific learning process (SPS) and their research method(s) in the learning environment (EE) context. The study showed that special educators had problems connecting observation and communication to formulate research questions and design experiments. They also have difficulty connecting critical skills to analysis, drawing conclusions, and reasoning. This demonstrates the abilities teachers face to ask questions, design experiments, draw conclusions, and make decisions in honest research.

In essence, the literature suggests that pre-service teachers often exhibit limited conceptual knowledge concerning Science Process Skills and their Biological Literacy. Studies have indicated that pre-service teachers generally have a low to moderate level of understanding of Science Process Skills, which can impact their ability to teach these skills to students. Additionally, while pre-service teachers may demonstrate a moderate level of biological literacy, their comprehension of Science Process Skills is often found to be lacking. This indicates a potential gap in their ability to effectively integrate scientific enquiry skills into their teaching of biological concepts.

The literature highlights a common theme regarding the conceptual knowledge of pre-service teachers, particularly in the areas of SPS and BL. Against the highlighted theme, the forthcoming discussion delves into the findings and implications of the current study concerning pre-service teachers’ conceptual understanding of SPS and their level of BL. The discussion analyses these findings, exploring whether they align with or contradict existing literature on pre-service teachers’ conceptual understanding of SPS. Additionally, the discussion extends to BL, scrutinising the reported moderate level observed by Kruea-In et al. (2015) and assessing its implications for the integration of scientific enquiry skills into the teaching of biological concepts. The goal is to uncover potential gaps in pre-service teachers’ ability to effectively impart both SPS and BL to their students.

6.2.1.1 Pre-service Teachers’ Performance on Science Process Skills

Pre-service teachers exhibit notable deficiencies in various science process skills, particularly in understanding plant taxonomy-based biological concepts. The analysis of specific skills, including classifying, measuring, operational definition, identifying and controlling variables, experimenting, hypothesising, predicting, interpreting data, and observation, highlights the shortcomings in both test performance and conceptual understanding. For instance, a concerning percentage of pre-service teachers struggled with fundamental skills such as classifying and measuring, with a substantial proportion failing to demonstrate competence in operational definition and identifying and controlling variables. The limitations extend to hypothesising and predicting skills, where none of the participants exhibited proficiency. While there is some encouragement in interpreting data skills, the overall picture points to a critical need for comprehensive reforms in teacher education programmes to address the identified deficiencies effectively.

These findings have broader implications for the education system's ability to cultivate essential science process skills among pre-service biology teachers. The inadequacies observed, despite prior exposure to Science Process Skills (SPS) concepts, underscore a critical gap in foundational understanding. This deficiency not only hindered pre-service teachers' capacity to effectively teach and communicate these concepts but also raised questions about the adequacy of current pedagogical approaches and the need for targeted interventions. The study emphasised the importance of investing in teacher training programmes that prioritise the development of science process skills, signalling the necessity for significant improvements in science education in Nigeria.

The findings of the current study are generally consistent with the existing literature on pre-service teachers' performance in Science Process Skills (SPS). The literature, as exemplified by Akinbobola and Afolabi (2010), Kruea-In et al. (2015), and Erkol and Ugulu (2014), consistently indicates that pre-service teachers tend to demonstrate a low to moderate level of understanding of SPS, with challenges in effectively teaching these skills to students. The current study aligned with this theme, revealing a foundational understanding in some SPS, such as classifying, but encountering challenges in areas like measuring, operational definition, observing, identifying and controlling variables, and predicting. This corroborates the existing literature's emphasis on the potential gaps in pre-service teachers' ability to integrate scientific inquiry skills into their teaching of biological concepts.

The findings also echo Molefe and Aubin's (2021) observations of challenges in linking relevant skills to various aspects of scientific enquiry, further underscoring the need for targeted support and training. Mbewe, Chabalengula and Mumba (2010) study found that pre-service teachers had good knowledge and some interest in the scientific process, but their understanding of the scientific process was poor. According to Mbewe et al. (2010) state that teacher candidates do not have sufficient cognitive science knowledge to help future students understand their own values. Overall, the study's results support the existing literature's portrayal of pre-service teachers facing conceptual challenges in SPS and BL, emphasising the importance of addressing these gaps for effective science education.

6.2.1.2 Preservice Teachers' Conceptual Understanding of Science Process Skills

The study revealed varying levels of conceptual understanding among pre-service teachers in different Science Process Skills (SPS). While the majority demonstrated a foundational understanding of classifying, some may need additional support. However, there was limited conceptual understanding in measuring, indicating challenges with precise language and concepts. The skills of operational definition and observation were perceived as abstract and challenging by participants.

Similarly, identifying and controlling variables were found to be abstract and challenging by most participants. Many pre-service teachers may not have adequate understanding of experimenting, pointing to potential issues in emphasising practical activities. Hypothesising and interpreting data proved to be challenging, suggesting a potential gap in how lecturers facilitate this skill. The majority exhibited poor knowledge in predicting, indicating challenges in training and reliance on textbooks. These findings underscore the need for targeted support and training to enhance pre-service teachers' grasp of these fundamental skills for effective science education.

The current study's finding align with and support the existing literature on pre-service teachers' conceptual understanding of Science Process Skills (SPS). The literature, represented by Akinbobola and Afolabi (2010), Kruea-In et al. (2015), Erkol and Ugulu (2014), Molefe and Aubin (2021), and Mbewe et al. (2010), consistently indicate that pre-service teachers tend to demonstrate a low to moderate level of understanding of SPS, facing challenges in effectively teaching these skills to students. The study's results corroborate this theme, revealing a foundational understanding in some SPS, such as classifying, while encountering challenges in areas like measuring, operational definition, observing, identifying and controlling variables, and predicting. The agreement with Molefe and Aubin's (2021) observations about challenges in linking relevant skills to various aspects of scientific enquiry underscores the need for targeted support and training. Additionally, Mbewe, Chabalengula, and Mumba's (2010) findings about pre-service teachers lacking sufficient conceptual knowledge of science process skills further align with the current study's emphasis on addressing gaps for effective science education. In summary, the findings of the study support and reinforce the existing literature's portrayal of pre-service teachers facing conceptual challenges in SPS and BL, highlighting the importance of addressing these gaps for effective science education.

6.2.1.3 Pre-service Teachers' Level of Biology Literacy.

The research study delved into the assessment of biological literacy among pre-service teachers and its implications for their utilisation of science process skills (SPS). Adopting Uno and Bybee's (1994) framework, the study categorises biological literacy into four levels, namely Nominal, Functional, Structural, and Multi-dimensional.

The findings indicate that pre-service teachers generally excel at the nominal level, showcasing proficiency in identifying and defining fundamental biological concepts, such as taxonomy. However, challenges become evident as the study progresses to higher levels of biological literacy. At functional level, a significant proportion of teachers struggle to connect the concept of bioremediation to bacteria and pollution reduction. The structural level reveals a complete lack of proficiency, as none of the participants could construct a dichotomous key, demonstrating a gap in understanding conceptual diagrams in biology. The multi-dimensional level further underscores deficiencies, with most of pre-service teachers failing to relate biology to other disciplines, emphasising the need for a more integrated and practical methods to teaching biology.

The study sheds light on critical areas where pre-service teachers face challenges in biological literacy, emphasising the interconnectedness of biological knowledge and how science process skills can be applied. While teachers exhibit competence in basic biological concepts, the research highlights deficits in their ability to apply this knowledge in real-world situations, employ higher-order thinking skills, and integrate biology with other disciplines.

6.2.1.4 Conclusion.

The findings on pre-service teachers' conceptual knowledge of Science Process Skills (SPS) revealed significant concerns about pre-service teachers' grasp of SPS, which are fundamental for scientific enquiry, academic achievement in science, and the development of scientific literacy. It is evident that there are notable disparities in their understanding of different SPS, with some skills, such as *classifying*, being relatively well-understood by most participants, while others, like operational definition, identifying and controlling variables, and hypothesising, posed significant challenges.

One particularly concerning area was the low comprehension of prediction, a skill crucial for scientific enquiry and critical thinking. Only a small percentage of pre-service teachers were able to provide correct definitions for this skill, indicating a substantial gap in their knowledge. This deficit in understanding prediction may hinder their ability to effectively teach and guide future students in the intricacies of scientific inquiry. The results provided evidence for several challenges contributing to pre-service teachers' inadequate acquaintance with SPS. These challenges included the lack of comprehensive training, an overreliance on textbooks, limited emphasis on SPS within the curriculum, time constraints, and personal gaps in their own experiences with these skills. Addressing these challenges requires targeted interventions, such as comprehensive training programmes, curriculum refinements, and customised support mechanisms to enhance educators' comprehension of SPS and their ability to impart these competencies to their students effectively.

The findings raise critical concerns about the state of science education and the readiness of pre-service teachers to conduct effective scientific investigations and guide their future students. To address these concerns and ensure that future generations of Nigerian students are well-equipped with essential science process skills, comprehensive reforms in science education are imperative. These reforms should prioritise pedagogical approaches that facilitate practical learning and invest in teacher development, ultimately promoting effective scientific enquiry and understanding among students.

6.2.1.5 Recommendation.

To enhance the development of science process skills (SPS) among pre-service teachers in the context of plant taxonomy, it is recommended to focus on several key strategies. Firstly, providing hands-on experiences and practical activities is crucial. The study highlighted that many pre-service teachers encountered difficulties in applying SPS in a practical manner, such as conducting experiments and making measurements. To address this, educators and curriculum designers should prioritise pedagogical approaches that emphasise hands-on learning and offer students concrete examples and opportunities to practise these skills within the domain of plant taxonomy. By engaging in experiential learning, pre-service teachers can develop a deeper understanding of how SPS is applied in real-world scenarios.

Secondly, there is a need to demystify abstract concepts. The study identified that pre-service teachers struggled with certain abstract concepts related to SPS, including operational definition and identification and control of variables. Educators should consider adopting pedagogical approaches that make these concepts more accessible and relevant to the complexities of plant taxonomy. Explaining these abstract concepts through practical examples and real-life applications can help pre-service teachers grasp their significance and facilitate their application in the specific context of plant taxonomy.

Thirdly, bridging the gap between theoretical knowledge and practical application is vital. The study revealed that many pre-service teachers faced challenges when attempting to apply their theoretical knowledge of SPS to the domain of plant taxonomy. Educators should adopt pedagogical approaches that assist students in closing this gap and translate scientific skills into real-world scenarios. This can be accomplished through the integration of case studies, problem-solving exercises, and project-based learning activities that require pre-service teachers to apply their theoretical understanding of SPS within the context of plant taxonomy. By providing opportunities for hands-on practice and application, pre-service teachers can develop a more comprehensive and nuanced understanding of SPS within plant taxonomy.

Lastly, providing additional support and guidance to pre-service teachers is crucial, especially for those grappling with abstract or challenging SPS. The study found that pre-service teachers may benefit from increased support and resources from lecturers to master these skills effectively. Educators should consider offering supplementary materials, extra practice opportunities, and timely feedback to enhance pre-service teachers' understanding and mastery of SPS. Implementing mentorship programmes, peer collaboration and regular progress evaluations can also provide a support system that assists pre-service teachers in developing their science process skills effectively.

6.2.2 How did pre-service teachers' use of science process skills to understand biological concepts based on plant taxonomy?

Section 6.2.2 focuses on the second research question: "How do pre-service teachers use Science Process Skills (SPS) to understand biological concepts based on plant taxonomy?" This section explores the application and utilisation of SPS by pre-service teachers in comprehending complex biological concepts, particularly within the framework of plant taxonomy.

The section begins by explaining the research approach chosen to address the second research question. It adopts a qualitative research approach, employing Focus Group Interviews (FGIs) as the primary method for data collection. This choice is meant to delve into the experiences, viewpoints, and practices of pre-service teachers regarding the application of SPS in understanding biological concepts, specifically those related to plant taxonomy. The qualitative nature of FGIs is justified, emphasising the potential to extract rich, contextualised insights. However, the text also acknowledges the subjective nature of qualitative data and potential biases, highlighting the importance of a critical interpretation of the findings.

The findings indicate a strong preference among pre-service teachers for using SPS as an integral tool in their approach to understanding complex biological concepts. SPS such as observation, identification, and hands-on experimentation are viewed as effective tools for tackling the intricacies of plant taxonomy.

The section discusses how these practical skills enhance hands-on learning experiences, allowing pre-service teachers to directly engage with plants and fostering better knowledge retention. Additionally, the use of SPS is seen as promoting collaborative learning, creating an interactive and enjoyable environment for exploring plant taxonomy. Despite this positive inclination towards SPS, the section also highlights challenges faced by pre-service teachers, including the lack of qualified instructors, difficulties in plant identification, financial constraints, and limited access to resources. The section also discusses how pre-service teachers perceive SPS not only as instructional tools but as prerequisites for effective teaching in the biological sciences. This recognition suggests potential avenues for curriculum development and instructional enhancement within pre-service teacher training, emphasising the cultivation of proficiency in SPS.

The conclusion of the section summarises the key findings, emphasising the strong inclination among pre-service teachers to employ SPS in understanding plant taxonomy-based biological concepts. This inclination aligns with existing literature and theoretical frameworks such as the Biological Literacy Framework and Cultural Historical Activity Theory (CHAT), providing an understanding of the significance and challenges associated with the integration of SPS in this context. The section concludes with recommendations.

To address Research Question 2, the study opted for a qualitative research approach, employing Focus Group Interviews (FGIs) as the primary method for data collection. The utilisation of FGIs holds the potential to extract rich, contextualised insights. It allows participants to articulate their thoughts, providing a more profound exploration of the details surrounding the integration of SPS in their learning. However, the effectiveness of FGIs is contingent upon the facilitator's skill in steering discussions and the participants' willingness to openly share their perspectives. As noted by Schoonenboom and Johnson (2017), the success of FGIs relies on the dynamic interplay between these factors, influencing the depth and authenticity of the data generated.

The qualitative nature of FGIs suited for capturing the complexity and diversity inherent in pre-service teachers' approaches to using SPS (Krueger & Casey, 2002). By engaging in group discussions, the study tapped into collective experiences, fostering a more holistic understanding of the challenges, motivations, and collaborative aspects associated with the application of SPS in the study of plant taxonomy. This approach is beneficial for exploring the depth of participants' perspectives, shedding light on the intricate dynamics of integrating SPS into the learning process.

While the qualitative nature of FGIs provides valuable insights, it is essential to acknowledge the inherent subjectivity and potential for social desirability bias (Krueger & Casey, 2002). Participants may shape their responses based on perceived expectations, and the facilitator's influence can impact the direction of discussions. As such, a critical lens is necessary when interpreting the findings, recognising the context-specific nature of qualitative data and its potential limitations.

Hogan and Maglienti (2001) conducted a comparative analysis of the efficacy of enquiry-based and traditional science instruction, focusing on middle school students' comprehension of concepts related to respiration and photosynthesis. Notably, students enrolled in enquiry-based classes exhibited a markedly superior understanding of key concepts and demonstrated enhanced performance in tasks requiring the application of Science Process Skills (SPS).

In a related exploration, Nadiah et al. (2021) scrutinised the Predict, Observe, Explain (POE) model as a framework for enquiry-based learning within the domain of high school biology. Their study explored the research indicating that the POE model catalyses the development of scientific literacy and reasoning skills. By explicitly prompting students to engage in SPS, this model contributes to a deeper understanding of biological concepts. Shifting the focus to the role of educators, Lakin and Wallace (2015) highlight the vital significance of the teachers' proficiency in science process skills for effectively facilitating student learning. Professional development programmes that concentrate on augmenting teachers' comprehension of SPS and integrating them into curriculum and instruction have been shown to yield substantial improvements in student outcomes related to these skills.

Windschitl and Calabrese Barton (2016) further contribute to this discourse by exploring the interconnection between science teachers' Pedagogical Content Knowledge (PCK) and students' achievements in science process skills. The study discerned that teachers possessing a deeper understanding of PCK, particularly PCK related to SPS, were more efficacious in assisting students in the development and application of these skills in the context of learning biological concepts. In a complementary investigation, a temporary system of support typically referred to as scaffolding, provided to learners during enquiry-based activities—on student performance in scientific enquiry tasks was the main focus of Tsai et al. (2011). The results underscored the potential of well-designed scaffolds in facilitating students' utilisation of SPS during independent research projects, leading to an improved grasp of biological concepts. This cumulative body of research collectively underscores the intricate nexus between instructional methodologies, teacher proficiency, and student outcomes in the cultivation of science process skills within the realm of biology education.

6.2.2.1 The Cogenerative Dialogue in the Present Study.

The cogenerative dialogue sessions with the pre-service teachers revolved around a comprehensive exploration of the challenges and perceptions associated with learning plant taxonomy. Through open discussions, participants highlighted the difficulties they faced in grasping the subject, emphasising issues with the identification and classification of numerous plants, especially when similarities to familiar species posed challenges. Notably, the dialogues brought to light concerns regarding the teaching methods employed by lecturers, including dissatisfaction with abstract approaches and a perceived lack of subject knowledge among some instructors. The sessions also served as a platform for pre-service teachers to propose solutions, ranging from the improvement of teaching methods to the employment of qualified educators with a passion for teaching.

In conjunction with the cogenerative dialogues, the application of the Cultural-Historical Activity Theory (CHAT) framework provided insights into the pre-service teachers' utilisation of SPS for understanding plant taxonomy-based biological concepts. Themes such as the preference for SPS, available resources, adherence to rules, time spent studying, and the motives behind using SPS were systematically analysed within the CHAT framework. Additionally, focus group interviews revealed eight themes related to the use of SPS in learning plant taxonomy, shedding light on the complexities of the learning process. Overall, the lessons drawn from these dialogues underscore the importance of addressing pedagogical challenges, providing adequate resources, and fostering interactive, collaborative learning experiences to enhance the understanding of plant taxonomy among pre-service teachers.

One of the significant insights obtained from the cogenerative dialogues was the identification of specific issues in the teaching of plant taxonomy. The pre-service teachers pointed out concerns related to the lecturers' teaching style, the lack of practical experience, and the abstract nature of the instruction. Additionally, discrepancies in the lecturers' subject knowledge and the hindrance caused by the vast scope of plant taxonomy were highlighted. The dialogues served as a platform for these teachers to articulate their perceptions, fostering an environment where challenges were openly discussed and potential solutions were proposed.

Furthermore, the cogenerative dialogues revealed a collective call for improvements in teaching methods, including suggestions for more hands-on, practical approaches, and the incorporation of unconventional teaching techniques. The pre-service teachers stressed the need for qualified instructors with educational backgrounds, highlighting the importance of pedagogical expertise in effectively delivering complex subjects like plant taxonomy. These insights underscored the significance of aligning teaching strategies with the needs and preferences of learners, advocating for a more engaging and effective educational experience.

The lessons taught during the cogenerative dialogues and the insights elicited from these sessions aligned with the literature while also providing additional nuances specific to the context of fourth-year pre-service teachers learning plant taxonomy. In the literature, the emphasis on enquiry-based learning models, such as the Predict, Observe, Explain (POE) model, as explored by Tausch and Reiss (2013), resonates with the insights from the cogenerative dialogues. Both highlight the importance of engaging students in science process skills (SPS) for a deeper understanding of biological concepts. The cogenerative dialogues underscored the challenges faced by pre-service teachers in applying SPS to plant taxonomy, aligning with the literature's recognition of the significance of educators' proficiency in SPS for effective student learning.

Similarly, Sun and Windschitl’s (2016) focus on the role of pedagogical content knowledge (PCK) in science teachers, particularly related to SPS, correlates with the challenges identified in the cogenerative dialogues regarding lecturers' teaching style and subject knowledge. The dialogues revealed a collective call for qualified instructors with educational backgrounds, echoing Sun and Windschitl's (2016) emphasis on teacher proficiency in SPS for facilitating student development.

However, the cogenerative dialogues provided additional context-specific insights, such as the dissatisfaction with abstract teaching methods and the need for hands-on, practical approaches. These nuances, specific to the challenges faced by pre-service teachers learning plant taxonomy, complement the literature by emphasising the importance of aligning teaching strategies with the complexities of the subject matter. The lessons and insights from the cogenerative dialogues both support and enrich the existing literature, offering a context-specific perspective on the challenges and potential solutions in the realm of plant taxonomy education for pre-service teachers.

6.2.2.2 Responses from the Interviews.

The findings from the interviews within the Cultural-historical activity theory (CHAT) framework reveal a strong inclination among pre-service teachers towards utilising SPS for learning plant taxonomy. Their preference stems from the perceived benefits of improved comprehension, mastery of topics, and heightened knowledge retention. The motivation for engaging with SPS extends beyond theoretical learning, with an emphasis on hands-on activities, group collaboration, and interactive learning experiences. The contextual factors shaping these preferences include the desire for more engaging and interactive learning environments, where SPS not only facilitate understanding but also contribute to a sense of adventure and motivation for further research.

However, challenges in utilising SPS for plant taxonomy were identified, ranging from issues with teaching approaches and a lack of qualified personnel to difficulties in naming, comparing, and identifying plants. Financial constraints, limited access to virtual laboratories, and obstacles in finding specific plants or leaves further impede the effective integration of SPS. Mixed views on rule adherence among lecturers highlight the complexity of implementing SPS in teaching, with some pre-service teachers reporting non-compliance with rules and others noting partial adherence or effective use of SPS in specific contexts. Despite these challenges, the findings underscore the importance of considering both the preferences and obstacles within the CHAT framework to better understand the dynamics of incorporating SPS in the learning process.

The findings from the interviews within the Cultural-historical activity theory (CHAT) framework align closely with the literature, providing support for the importance of science process skills (SPS) in the learning process. Both the interview results and the literature emphasise the positive impact of enquiry-based and interactive learning methods, especially when integrating SPS into the curriculum. In both the interview findings and the literature, there is a consensus on the benefits of utilizing SPS for learning biological concepts. Pre-service teachers in the interviews express a strong inclination toward SPS, citing improved comprehension, mastery of topics, and heightened knowledge retention. Similarly, the literature, represented by studies such as Hogan and Maglienti (2001), Tausch and Reiss (2013), Yager and Klopfer (2015), Sun and Windschitl (2016), and Tsai et al. (2011), consistently supports the effectiveness of enquiry-based and interactive approaches that incorporate SPS. The literature highlights how these approaches enhance students' understanding of biological concepts and contribute to the development of scientific literacy and reasoning skills.

This finding also aligns with the existing literature that underscores the significance of SPS in promoting scientific literacy among students (Krauja et al., 2018). SPS are fundamental components of scientific literacy, and pre-service teachers view them as essential tools to facilitate learning and understanding. Chabalengula et al. (2012) stress the need for science teachers to possess experience, knowledge, and expertise in SPS to effectively impart biological concepts to students.

Moreover, the challenges identified in both the interview findings and the literature, such as issues with teaching approaches, a lack of qualified personnel, financial constraints, and limited access to resources, underscore the complexity of implementing SPS effectively. The mixed views on rule adherence among lecturers in the interview findings also align with the broader discourse in the literature, acknowledging the challenges associated with integrating SPS into teaching practices. The interview findings within the CHAT framework are consistent with the existing literature, emphasising the value of incorporating science process skills into biology education to foster a deeper understanding of biological concepts and enhance students' scientific literacy.

6.2.2.3 Conclusion.

In understanding how pre-service teachers utilise Science Process Skills (SPS) to comprehend biological concepts based on plant taxonomy, the findings reveal a strong inclination among pre-service teachers to employ SPS, including observation, identification, and hands-on experimentation, as integral tools for understanding complex biological concepts like plant taxonomy. This inclination aligns seamlessly with existing literature emphasising the vital role of SPS in promoting scientific literacy among students. Recognising these skills as fundamental components of scientific literacy underscores their importance in facilitating learning and understanding, echoing the sentiments of Chabalengula et al. (2012). The study underscores the pedagogical value of incorporating hands-on and experiential learning approaches, aligning with established literature that highlights the effectiveness of SPS in promoting scientific literacy.

The emphasis on the need for science teachers to possess experience, knowledge, and expertise in SPS suggests a potential avenue for curriculum development and instructional enhancement within pre-service teacher training. This finding advocates for the deliberate integration of SPS into teacher education programs, emphasising the cultivation of proficiency in SPS as an integral aspect of preparing future biology educators.

Despite the strong preference for SPS, pre-service teachers face challenges in their utilisation of plant taxonomy education. There are quite a number of burning issues such as the lack of qualified instructors, difficulties in plant identification, financial constraints, and limited access to resources pose hurdles. These challenges underscore the necessity for comprehensive teacher training programmes that align with Cultural Historical Activity Theory (CHAT) principles, which focus on developing expertise within a community of practice. The study provides a detailed understanding of the sociocultural aspects of learning, emphasising the role of SPS in mediating activities within the specific cultural and educational context.

The finding contributes valuable insights that extend beyond the realm of pre-service teacher education, with implications for curriculum development, instructional enhancement, and the broader domain of science education. The alignment of findings with theoretical frameworks such as the Biological Literacy Framework and CHAT enhances the theoretical robustness of the study, providing an extensive understanding of the significance and challenges associated with the integration of SPS in the context of plant taxonomy-based biological education.

6.2.2.4 Recommendation.

Implementing comprehensive teacher training programmes that focus on equipping educators with Science Process Skills (SPS) and pedagogical expertise is imperative. Educational institutions should collaborate with the Ministry of Education to design and execute these programmes, ensuring a standardised and effective approach. By integrating SPS training into teacher education, institutions can better prepare future biology educators to incorporate these skills into plant taxonomy education. This collaborative effort between educational institutions and governmental bodies is essential for the successful implementation of enhanced teacher training programs.

Addressing the challenge of a lack of qualified instructors proficient in teaching plant taxonomy through SPS requires a strategic approach. Educational institutions, in coordination with the Ministry of Education, should prioritise hiring qualified instructors with expertise in both plant taxonomy and effective SPS application. This joint effort ensures that educators possess the necessary skills to impart SPS-based knowledge to pre-service teachers, fostering a robust foundation for understanding plant taxonomy. By actively recruiting and supporting qualified instructors, the education system can overcome challenges associated with instructor shortages and enhance the quality of plant taxonomy education.

Providing financial support to overcome obstacles related to limited access to resources, including virtual laboratories, is crucial. Government agencies, in collaboration with educational institutions, should allocate funds to procure necessary materials and technologies. This collaborative funding approach ensures that institutions have the resources needed to create a conducive environment for implementing SPS in plant taxonomy education. This joint effort between government bodies and educational institutions promotes technological integration, addressing challenges associated with resource constraints.

Integrating Science Process Skills into the curriculum of pre-service teacher education programmes is essential for long-term success. Curriculum development bodies, in collaboration with educational institutions, should design curriculum frameworks that prioritise the cultivation of proficiency in SPS. This integrated approach ensures that future biology educators receive a well-rounded education, aligning with the principles of effective SPS application. By collectively working on curricular enhancements, curriculum developers and educational institutions contribute to a more robust and experientially driven approach to biological concepts among pre-service teachers.

6.2.3 What are the factors influencing pre-service teachers' use of SPS to understand biological concepts based on plant taxonomy?

To address Research Question 3, which investigates the factors influencing pre-service teachers' utilisation of science process skills (SPS) for understanding biological concepts within plant taxonomy, a comprehensive qualitative research approach was adopted. This approach sought to delve into the detailed aspects of pre-service teachers' experiences and perceptions.

The primary method employed for data collection in response to Research Question 3 was the cogenerative dialogue. This interactive and reflective discussion involved pre-service teachers, a lecturer, and the researcher. Through this qualitative method, participants engaged in conversations that aimed to uncover the underlying factors influencing their application of SPS in the context of plant taxonomy. The cogenerative dialogue provided a platform for participants to express their views, share experiences, and collaboratively identify aspects that either facilitated or hindered the effective use of SPS.

Additionally, the focus group interview, another qualitative method, was utilised to gather collective insights from pre-service teachers. By bringing together small groups of participants, the aim was to foster a dynamic discussion that could reveal shared perspectives on the factors influencing their engagement with SPS. The utilisation of the focus group interview as a supplementary method served to enhance the thorough examination conducted through the cogenerative dialogue. This dual-method approach significantly contributed to the attainment of a more holistic understanding of the intricate dynamics at play in the factors influencing pre-service teachers' application of SPS within the context of plant taxonomy.

It is imperative to recognise and duly contemplate the inherent constraints associated with qualitative research methodologies. One notable limitation pertains to the potential introduction of subjectivity into the research findings. Additionally, the challenge of generalisability, intrinsic to qualitative investigations, warrants acknowledgement. These considerations underscore the necessity for a detailed interpretation of the study outcomes, mindful of the inherent qualitative research limitations. However, the emphasis on qualitative methods for this research question aligns with the goal of exploring the depth and context-specific intricacies of pre-service teachers' experiences with SPS within plant taxonomy. The qualitative approach allows a detailed exploration of factors that might not be easily quantifiable (Tenny et al., 2022).

In their seminal work, Shope (2006) delved into the repercussions of an enquiry-based plant taxonomy course on the cognition of PST. The study illuminated the positive impact of this pedagogical approach on participants' understanding of plant structures and their adept utilisation of Science Process Skills (SPS) for enquiry. Noteworthy advancements were observed in SPS application, encompassing skills such as observation, classification, and inference, thereby underscoring the efficacy of enquiry-based methods in fortifying both scientific content and process skills. Building upon this foundation, Valanides and Angeli (2008) undertook an examination of the nuanced interplay between prior knowledge and the effectiveness of a plant taxonomy learning package tailored for preservice science teachers. The results underscored the important role of prior knowledge in influencing learning outcomes, with proficiency in both plant biology and SPS significantly shaping the efficacy of the instructional intervention. This elucidation highlights the imperativeness of addressing knowledge gaps as a prerequisite to engaging learners in taxonomic activities.

Echoing this sentiment, Canuto (2023) explored pre-service teachers' initial conceptions of plant science and classification. Their investigation revealed a spectrum of varied and often inaccurate understandings among participants. The authors advocate for a tailored instructional approach that not only rectifies misconceptions but also explicitly imparts taxonomic processes alongside relevant SPS, such as observation, comparison, and inference. This approach is posited as essential for fostering a more accurate and nuanced understanding of plant science.

In a comparative vein, Murphy (2012) assessed the comparative effectiveness of an enquiry-based plant taxonomy unit against a traditional lecture-based approach for pre-service biology teachers. The findings indicated that the enquiry-based group exhibited greater gains in both plant knowledge and SPS, encompassing skills like questioning, data analysis, and problem-solving. This suggests the potential of enquiry-based instruction in fostering deeper learning and skill development in PST.

Expanding the scope to field-based experiences, Jeronen et al. (2016) delved into the impact of such experiences on pre-service teachers' comprehension of plant biodiversity and their confidence in employing plant taxonomy. Participants engaged in field activities demonstrated significant improvements in both areas, highlighting the value of authentic experiences in not only augmenting knowledge but also enhancing the practical application of SPS within real-world contexts. This collective body of research underscores the intricate relationship between instructional methodologies, prior knowledge, and experiential learning in shaping the proficiency of PST in plant taxonomy and related SPS.

6.2.3.1 Responses from the Interviews: Factors That Shaped the Teachers' Use of SPS to Understand the Biological Concept

Pre-service teachers consistently expressed a preference for incorporating Science Process Skills (SPS) into their learning, citing its positive impact on the comprehension of course materials. For example, a pre-service teacher stated, "It will make us understand the course better. Because if you can see and observe, you will be able to understand" (FGI 3II PST 3). The use of SPS was also associated with the mastery of topics, as teachers believed that hands-on activities facilitated a deeper understanding. Another pre-service teacher remarked, "In addition, it is good to use SPS to understand a concept or a topic because it will aid mastery of the topic" (FGI 3II PST 6). In support of this finding, Ango (2002) submitted that active participation in hands-on practical activities is essential for students to enhance their scientific comprehension and competence in the application of scientific methodologies for problem-solving. This engagement significantly contributes to elevating the calibre and breadth of their scientific knowledge. Moreover, involvement in practical work facilitates the acquisition of skills essential for the application of scientific concepts in real-world scenarios, enabling students to establish meaningful connections between scientific principles and their daily experiences (Triwiyonoa, & Pandac, 2019).

This indicates that pre-service teachers have a strong inclination towards integrating SPS into their learning practices. This inclination is substantiated by their belief in the positive impact of SPS on the comprehension of course materials. Their comments emphasise the perceived enhancement of plant taxonomy-based biological concept understanding through the incorporation of SPS. Their comments also underscore the belief that hands-on activities, facilitated by SPS, contribute to a deeper and more thorough understanding of specific subjects or concepts related to plant taxonomy. In line with this finding, Molefe and Aubin (2021) indicate a positive disposition among pre-service teachers regarding the incorporation of SPS into their learning methodologies. According to Molefe and Aubin (2021) and Özer and Sarıbaş (2022), participants expressed the belief that SPS could significantly augment their comprehension of scientific concepts and principles, concurrently enhancing their proficiency in problem-solving. Moreover, the study identified a notable inclination among pre-service teachers to integrate SPS into their future teaching practices. In contrast, Schuster et al. (2017) argue that it cannot be assumed that the same method is best for teaching content and method and that the two should be studied together. They argue that science curricula and teaching methods differ depending on which part of the research is addressed, such as the main ideas in the discipline or applications of science and technology

Furthermore, pre-service teachers favoured SPS for its contribution to knowledge retention, enabling them to remember and apply concepts. A pre-service teacher noted, "I prefer to use the skill because it aids my retention" (FGI 4III PST 2). Engagement in hands-on activities, particularly those involving SPS, was highly valued for creating interactive learning experiences and providing opportunities for group work and collaboration. A pre-service teacher explained, "It is interesting to use SPS to learn plant taxonomy since it involves all of us working together to classify plants" (FGI 3II PST 1). Additionally, the use of SPS was linked to increased motivation for research and a deeper interest in exploring plant-related topics. A pre-service teacher noted, "Yes, because it gives us the advantage to interact with our colleagues and share ideas when we are in a group. If you are working in a laboratory or when you go on tours to the botanical garden, forest, and Herbarium" (FGI 4III PST 5).

This suggests that pre-service teachers place significant value on SPS for various reasons. Firstly, the preference for SPS is associated with their positive impact on knowledge retention, and this conveys that pre-service teachers believe SPS enhance their ability to remember and apply concepts related to plant taxonomy. Moreover, engagement in hands-on activities, particularly those involving SPS, is highly regarded. The finding also indicates that the interactive nature of SPS contributes to a positive and engaging learning experience. The emphasis on collaborative efforts, such as group work and classification activities, underscores the perceived value of SPS in creating dynamic and participatory learning environments.

In support of this finding, Molefe and Aubin (2021) noted that pre-service teachers place a significant value on SPS for various reasons, including enhanced understanding of science concepts and principles as well as improved problem-solving skills. However, Mumba et al. (2019) argue that there may be a lack of understanding of SPS among teachers, which may affect their ability to teach these skills effectively.

Additionally, the finding suggests that the use of SPS is linked to increased motivation for research and a deeper interest in exploring plant-related topics. In other words, the hands-on and collaborative nature of SPS not only enhances learning but also fosters a sense of curiosity and interest in further exploration (Deksissa et al., 2014).

Contextual factors played a significant role, with pre-service teachers finding SPS enjoyable in the context of learning plant taxonomy, making the process both fun and interactive. A pre-service teacher expressed, "It makes learning fun and interactive" (FGI 3I PST 6). The preference for SPS was closely tied to practical methods, such as experimenting, which added an adventurous aspect to learning. A pre-service teacher elaborated, "Identification skill and experimental skill. Because picking the leaves to cook it is actually an experimental procedure" (FGI 4IV PST 4). This suggests that contextual factors strongly influence pre-service teachers' perceptions of SPS in the context of learning plant taxonomy. Specifically, the pre-service teachers find SPS enjoyable, describing the learning process as both fun and interactive. It implies that the incorporation of SPS contributes to a positive and engaging learning environment, aligning with the idea that enjoyment and interactivity enhance the overall learning experience (Özer & Sarıbaş, 2022). The finding indicates that the preference for SPS is closely linked to practical methods, particularly those involving experimentation. It also suggests that the hands-on and experimental nature of SPS aligns with the pre-service teachers' perception of practical methods as adventurous and engaging (Molefe & Aubin, 2021). This connotes that the application of SPS is not only enjoyable but also aligns with a preference for hands-on, experiential learning approaches.

However, challenges in utilising SPS were reported. Some pre-service teachers faced difficulties due to the lack of qualified personnel proficient in teaching plant taxonomy using SPS. A pre-service teacher pointed out, "The studying of plant taxonomy can be very stressful, and the lecturers did not teach the topic properly, leading to us not having an interest in the topic" (FGI 4IV PST 1). The challenges were also attributed to lecturers using complex materials instead of practical activities, impacting interest. A pre-service teacher highlighted, "The problem of lecturers dropping cumbersome materials for the topic instead of taking us through practical activities" (FGI 4III PST 4). Moreover, some teachers faced challenges in naming, comparing, and identifying plants due to complex characteristics and a multitude of species. A pre-service teacher explained, "The course is very complex, which makes it very difficult for us to start naming different trees due to some trees having similar characteristics" (FGI 3I PST2). Financial constraints, a lack of access to virtual laboratories, and difficulties in finding specific plants were additional challenges mentioned. A pre-service teacher stated, "One of the challenges is financial constraints, and using this skill will make you travel and spend some money. Another one is the lack of devices (gadgets) for the virtual laboratory" (FGI 4IV PST 1).

The findings reveal a dual nature of pre-service teachers' perceptions and utilisation of SPS in the context of learning plant taxonomy. On one hand, there is a clear inclination towards the positive impact of SPS on comprehension, topic mastery, and knowledge retention (Mumba et al., 2019; Özer & Sarıbaş, 2022; Irwanto, 2023). Pre-service teachers expressed a preference for incorporating SPS into their learning, emphasising its role in facilitating a deeper understanding of course materials and enhancing the mastery of topics. This positive sentiment extends to the practical aspects of hands-on activities involving SPS, which are valued for creating interactive learning experiences, fostering group collaboration, and generating motivation for research (Özer & Sarıbaş, 2022; Irwanto, 2023).

However, amidst these positive perceptions, challenges in the effective utilisation of SPS emerge. A notable obstacle is the reported lack of qualified personnel proficient in teaching plant taxonomy using SPS (Adlim et al., 2018). This raises concerns about the quality of instruction and the impact on students' interest and engagement. Additionally, the complexity of teaching approaches, involving cumbersome materials rather than practical activities, is highlighted as a hindrance to effective learning (Irwanto, 2023). The intricate nature of the course content, leading to difficulties in naming and identifying plants, further adds to the challenges. Finally, practical constraints, including financial limitations and issues related to access and resources for virtual laboratories, contribute to the multifaceted challenges faced by pre-service teachers.

In light of these findings, it becomes apparent that while the perceived benefits of SPS are acknowledged, addressing challenges related to instructional personnel, teaching methods, course complexity, and practical constraints is imperative for optimising the integration of SPS into the plant taxonomy education of pre-service teachers. This complex interplay between positive influences and challenges underscores the complexities associated with implementing practical, hands-on approaches in the educational context. Addressing the challenges demands a critical examination of institutional support, pedagogical approaches, and resource allocation. A fundamental shift toward recruiting qualified lecturers with expertise in utilising SPS and fostering an environment conducive to practical, hands-on learning is imperative. Furthermore, the strategies to mitigate financial constraints, improve access to essential resources, and streamline teaching approaches are crucial for overcoming the identified challenges.

Recognising the multifaceted nature of factors influencing pre-service teachers' use of SPS in plant taxonomy education is crucial for informed pedagogical decisions. Embracing the positive aspects while strategically addressing the challenges is paramount for creating a robust educational framework that nurtures a deep understanding of biological concepts rooted in plant taxonomy.

6.2.3.2 CHAT and Biological Literacy Perspectives of Factors Influencing Pre-service Teachers' Use of SPS to Understand Plant Taxonomy-Based Biological Concepts.

The study's findings on the factors influencing pre-service teachers' utilisation of Science Process Skills (SPS) in comprehending biological concepts, specifically centred on plant taxonomy, can be analysed through the perspectives of both Cultural-Historical Activity Theory (CHAT) and the Biological Literacy Theoretical Framework. From a CHAT standpoint, the study underscores the mediating role of SPS artefacts in pre-service teachers' actions. It aligns with the generational development of CHAT by recognising the evolution of SPS as a dynamic tool for collaborative learning within interconnected activity systems. The reported challenges in implementing SPS reveal contradictions within the activity system, where the positive perception of SPS coexists with structural tensions, emphasising the need for resolution to optimise its integration.

The integration of CHAT showcases the dynamic interplay between the mediated actions within the activity system and the levels of biological literacy achieved through SPS. The identified challenges within the activity system represent obstacles that, when addressed, can optimise the integration of SPS into plant taxonomy education and foster comprehensive biological literacy among pre-service teachers. Recognising the interconnectedness of these frameworks provides a holistic understanding of the complex factors influencing pre-service teachers' use of SPS in comprehending biological concepts based on plant taxonomy.

6.2.3.3 Conclusion.

The examination of factors influencing pre-service teachers' utilisation of Science Process Skills (SPS) to comprehend plant taxonomy-based biological concepts reveals a subtle landscape. The positive perceptions expressed by pre-service teachers regarding the integration of SPS into their learning underscore its potential benefits, including enhanced comprehension, mastery of topics, and increased motivation for research. The hands-on and collaborative nature of SPS, as highlighted by the participants, not only enriches the learning experience but also fosters a sense of curiosity and interest in exploring plant-related topics.

However, amidst these positive sentiments, significant challenges were identified. The reported lack of qualified personnel proficient in teaching plant taxonomy using SPS raises concerns about the quality of instruction and its impact on students' interests and engagements. Complex teaching methods, practical constraints, and difficulties in navigating the intricate nature of plant taxonomy courses further contribute to the multifaceted challenges faced by pre-service teachers.

6.2.3.4 Recommendation.

Based on the findings of the study, several recommendations emerge to enhance the teaching of science process skills (SPS) in the context of plant taxonomy for pre-service teachers. Firstly, teacher educators should provide comprehensive training on effective instructional strategies for teaching SPS. This training should encompass both theoretical and practical components in order to equip pre-service teachers with the necessary knowledge and skills.

Furthermore, it is crucial to align teaching approaches with the preferences of pre-service teachers, who tend to favour experiential learning methods. Therefore, teacher educators and policymakers should focus on designing hands-on, collaborative teaching approaches that actively engage pre-service teachers in the learning of SPS. By integrating real-world contexts and experiences, these approaches can effectively demonstrate the practical applications and significance of SPS. To bolster the effective teaching and learning of plant taxonomy using SPS, sufficient resources and infrastructure should be made available. This may include providing pre-service teachers with access to qualified personnel who can guide them through the learning process, as well as equipping them with virtual laboratories and a diverse range of plant specimens for hands-on exploration.

To illustrate the implementation of these recommendations, several specific examples can be considered. For instance, teacher educators can develop a dedicated course centred around teaching plant taxonomy using SPS. This course would cover topics such as the various types of SPS, strategies for integrating SPS into plant taxonomy lessons, and methods for evaluating student comprehension of SPS. Additionally, collaborations between teacher educators and botanical gardens or other relevant organisations can be established. These partnerships would allow pre-service teachers to gain first-hand experience and practice with SPS in authentic settings. Activities such as field trips to botanical gardens or engaging in plant taxonomy research alongside scientists can greatly enhance the pre-service teachers' understanding and application of SPS.

To facilitate the implementation of these recommendations, policymakers should allocate the necessary funds to support the development and execution of innovative teaching approaches for plant taxonomy. This funding could be utilised for teacher training, procurement of necessary equipment, and the creation of online learning resources to ensure wide accessibility.

6.3 The Frameworks of the Study through the lens of the Discussed Results

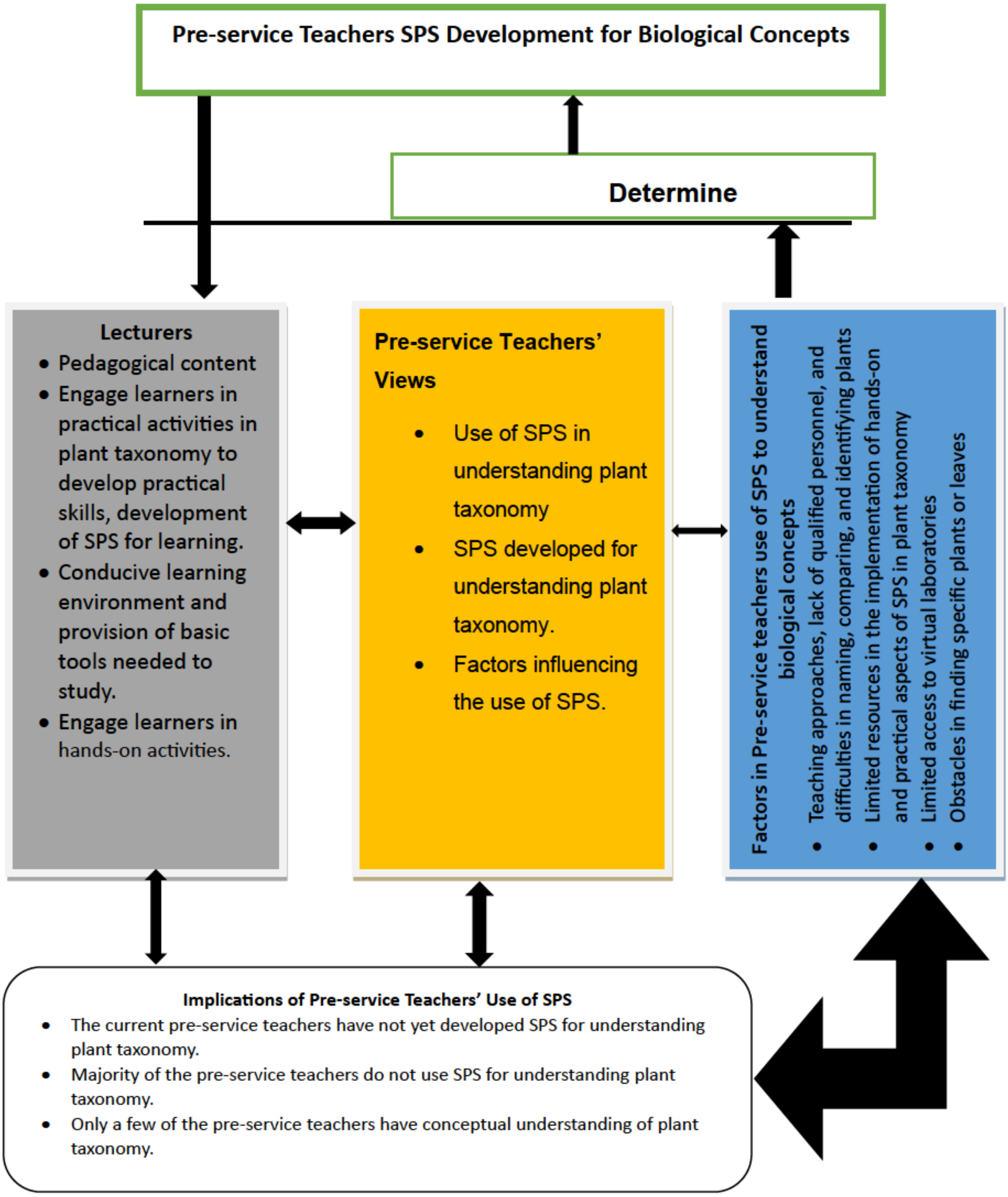
This study utilised a conceptual framework diagrammatically represented in Figure 6.1, to explore pre-service teachers' use of science process skills in understanding biological concepts based on plant taxonomy at a Nigerian University. The use of a conceptual framework in the study was informed by the need to integrate diverse conceptual and theoretical perspectives from existing literature. A conceptual framework is a culmination of interconnecting similar concepts that provide explanations, predictions, or a comprehensive understanding of the phenomenon under investigation, contributing to the comprehension of the research problem at hand (Maxwell, 2009). The process of developing a conceptual framework resembles an inductive approach, where individual conceptual fragments amalgamate to form a comprehensive map of potential relationships. Therefore, a conceptual framework serves as a crucial foundation and roadmap for the study. It assists in organising and synthesising pertinent concepts from the existing literature, guiding research and analysis effectively.

The nexus between conceptual understanding, biological literacy, and the development of Scientific and Pedagogical Skills (SPS) among pre-service teachers for biological concepts reveals a multifaceted landscape. While pre-service teachers exhibit a foundational grasp of biological classification, they encounter challenges in operationalising concepts, measuring phenomena, and conducting experiments. Additionally, their proficiency in biological literacy varies across nominal, functional, structural, and multi-dimensional levels, highlighting disparities in connecting concepts and understanding interdisciplinary relationships within biology.

Moreover, the effective utilisation of SPS in teaching biological concepts is contingent on various factors. Issues such as teaching approaches, a shortage of qualified personnel, and difficulties in identifying plants pose hurdles. Resource limitations impact hands-on and practical aspects of SPS implementation, while restricted access to virtual laboratories hinders technological integration. Despite these challenges, there is a pronounced inclination among pre-service teachers to leverage SPS, particularly in plant taxonomy. The recognition of SPS as an empowering tool for plant differentiation, its efficacy in promoting collaborative learning, and its contribution to a hands-on educational experience underscore the potential of technology in addressing specific impediments within the realm of biological education.

Figure 6.1

Theoretical Framework and the Phenomenon Being Explored in The Study



6.4 Knowledge Contribution of the Study

The study makes several knowledge contributions within the domain of science education, particularly concerning the development of Science Process Skills (SPS) among pre-service biology teachers in the context of plant taxonomy-based biological concepts. Firstly, it sheds light on the specific deficiencies in various SPS, such as operational definition, identifying and controlling variables, experimenting, hypothesising, predicting, and observation, among pre-service teachers. This understanding provides educators, curriculum developers, and policymakers with targeted insights into areas that require emphasis and improvement in teacher training programmes.

Moreover, the study extends the current knowledge base by identifying potential factors influencing the development of SPS. The examination of external factors like financial constraints, difficulties in plant identification, and the availability of qualified instructors adds depth to the understanding of the challenges faced by pre-service teachers. This knowledge is crucial for designing interventions and support mechanisms that address these specific hurdles, thereby enhancing the overall effectiveness of teacher training programmes.

The findings also underscore the influence of teaching methods on pre-service teachers' understanding of SPS. By emphasising the potential limitations of traditional teaching approaches and suggesting a need for more active and experiential learning methods, the study contributes valuable insights into pedagogical strategies. This knowledge can inform instructional design and curriculum development, promoting the adoption of teaching methods that better facilitate the cultivation of SPS among aspiring biology educators.

Additionally, the study advocates for a comprehensive and holistic approach to addressing the identified deficiencies, encompassing curriculum reassessment, pedagogical reform, professional development opportunities, resource provisioning, collaborative learning, effective assessment, real-world application, and advocacy for comprehensive science education. This comprehensive set of recommendations contributes a practical roadmap for educational stakeholders and policymakers aiming to enhance the preparation of pre-service biology teachers, ensuring they are equipped with robust SPS to effectively impart scientific knowledge to their future students. The study's knowledge contributions have implications for the improvement of science education in Nigeria and provide a foundation for further research and targeted interventions in pre-service teacher training programs.

6.5 Limitations and Delimitations of the Study

The investigation provides essential perspectives on developing Science Process Skills (SPS) among aspiring biology educators in the context of understanding plant taxonomy-based biological concepts, and grappling with certain limitations. Firstly, the sample size poses a constraint on the generalisability of findings. The participants may not adequately represent the diversity of backgrounds and experiences among pre-service biology teachers, thereby limiting the external validity of the study's results. Additionally, the focus on one educational institution may curtail the broader applicability of the findings to other regions or institutions with distinct characteristics.

Another notable limitation lies in the cross-sectional design adopted by the study. While it provides a snapshot of pre-service teachers' SPS at a specific point in time, this design might overlook potential changes in SPS development throughout their teacher training programmes. In the study, dependence on self-recorded information further introduces the possibility of social desirability bias, potentially impacting the accuracy of participants' responses regarding the utilisation of SPS for understanding plant taxonomy. These methodological considerations underscore the need for caution in generalising the study's findings and suggest avenues for future research to explore the longitudinal aspects of SPS development among pre-service biology teachers.

Furthermore, the study briefly touches on external factors such as financial constraints, a lack of qualified instructors, and difficulties in plant identification that may influence the utilisation of SPS. However, the limited exploration of these factors leaves questions unanswered about their nuanced impact. Additionally, the absence of a comprehensive examination of pedagogical strategies employed in the teacher training programmes hinders a thorough grasp of the influence of teaching methods on SPS comprehension. The study's acknowledgement of these limitations provides a foundation for refining future research efforts in examining the intricacies of pre-service teachers' development of Science Process Skills in the context of plant taxonomy-based biological concepts. There was no timeline given for the learning phase for these pre-service teachers for the cogenerative dialogue and this was because they were busy and had limited time to participate in the study.

6.6 Recommendations for Further Research

Future research should examine the effectiveness of diverse pedagogical strategies aimed at enhancing pre-service teachers' proficiency in Science Process Skills (SPS), with a specific focus on methods that foster critical thinking and conceptual clarity in plant taxonomy education. Comparative studies could assess the impact of different instructional approaches, shedding light on the strategies that prove most beneficial in cultivating a robust understanding of SPS among aspiring biology educators.

Another avenue for further research lies in investigating the integration of technology, such as virtual laboratories and interactive simulations, to enhance pre-service teachers' grasp of SPS. This enquiry should explore how technology can address practical constraints and improve resource accessibility, providing insights into its potential to facilitate effective learning experiences. Additionally, research could explore the impact of collaborative learning experiences on the development of SPS, examining how group activities and peer collaboration contribute to a deeper understanding of plant taxonomy concepts and the effective application of SPS.

Further research should conduct thorough evaluations of existing teacher training programmes, focusing on the integration of SPS. Assessing the strengths and weaknesses of current approaches will help identify areas for improvement, ensuring that pre-service teachers are adequately prepared for effective science education. Moreover, investigating the correlation between pre-service teachers' proficiency in SPS and the quality of science education delivered to students will provide valuable insights into how the effective utilisation of SPS influences students' understanding and engagement with plant taxonomy-based biological concepts. This study has the potential to guide the improvement of more impactful teacher training initiatives and science education methodologies.

6.7 Concluding Comments

The exploration of pre-service teachers' conceptual knowledge of Science Process Skills (SPS) and their utilisation in understanding plant taxonomy-based biological concepts reveals a nuanced landscape. The identified deficiencies in various SPS among pre-service biology teachers, particularly in operational definition, identifying and controlling variables, experimenting, hypothesising, predicting, and observation, underscore critical gaps in their preparation for future roles as science educators. While there is a positive inclination among pre-service teachers to use SPS for understanding complex biological concepts, challenges such as the lack of qualified instructors, difficulties in plant identification, financial constraints, and limited access to resources pose significant hurdles.

The findings underscore the need for targeted interventions, curriculum redesign, and enhanced professional development opportunities to address the identified deficiencies in science process skills. The study advocates for a holistic approach, including training programmes, curriculum refinements, resource provisioning, and the implementation of specialised initiatives. The long-term implications of these deficiencies are highlighted, pointing towards potential challenges in delivering quality science education in schools.

Furthermore, the study highlights the importance of aligning teacher training programmes with the demands of effective science teaching. Recommendations encompass curricular reassessment, pedagogical reform, professional development opportunities, resource provisioning, collaborative learning, effective assessment, real-world application, and advocacy for comprehensive science education. By addressing these issues, educational stakeholders can contribute to the enhancement of science education in Nigeria, ensuring the preparation of educators capable of instilling a strong foundation in scientific enquiry and analysis in their students.

References

.

Abawi, K. (2013). Data collection instruments (questionnaire & interview). *Geneva Foundation for Medical Education and Research*.

Abutabenjeh, S., & Jaradat, R. (2018). Clarification of research design, research methods, and research methodology: A guide for public administration researchers and practitioners. *Teaching Public Administration*, *36*(3), 237-258.

Adebisi, T. A. (2014). Higher education and skills development: An overview of Nigerian National Policy on Education (NPE). *International Journal of Development and Sustainability*, *3*(12), 2218-2227.

Adebusuyi, O. F., Olajumoke, T. O., Akinnifesi, J. B., & Karinatei, S. M. (2023). The effectiveness of computer-based simulations and traditional hands-on activities on secondary school students' performance and science process skills in practical Chemistry. *Journal of Education in Black Sea Region, 8*(2), 108-120.

Adedoyin, A. O., & Bello, G. (2018). Conceptions of the nature of science held by undergraduate pre-service Biology teachers in south-west Nigeria. *MOJES: Malaysian Online Journal of Educational Sciences*, *5*(1), 1-9.

Adlim, M., Nuzulia, R., & Nurmaliah, C. (2018). The effect of conventional laboratory practical manuals on pre-service teachers' integrated science process skills. *Journal of Turkish Science Education*, *15*(4), 116-129.

Aina, J. K., & Langenhoven, K. (2015). Teaching method in science education: The need for a paradigm shift to peer instruction (PI) in Nigerian schools. *International Journal of Academic Research and Reflection*, *3*(6), 6-15.

Ajanigo, J. A., & Aboritoli, S. (2021). A study of the attitude of senior secondary school students towards science process skills. *International Journal of Advanced Research*, *9*(5), 372–377. https://doi.org/10.21474/ijar01/12847

Ajibola, M. A. (2008). Innovations and curriculum development for basic education in Nigeria: Policy priorities and challenges of practice and implementation. *Research Journal of International Studies, 8*, 51-58.

Akani, O. (2015). Laboratory teaching: Implication on students' achievement in chemistry in secondary schools in Ebonyi State of Nigeria. *Journal of Education and Practice, 6*(30), 206-213.

Akben, N. (2015). Improving science process skills in science and technology course activities using the inquiry method. *Egitim Ve Bilim-Education And Science*, *40*(179).

Akcay, B., & Akcay, H. (2015). Effectiveness of science-technology-society (STS) instruction on student understanding of the nature of science and attitudes toward science. *International Journal of Education in Mathematics, Science and Technology, 3*(1), 37-45.

Akhtar, S., Shah, S. W. A., Rafiq, M., & Khan, A. (2016). Research design and statistical methods in Pakistan Journal of Medical Sciences (PJMS). *Pakistan Journal of Medical Sciences*, *32*(1), 151.

Akinbobola, A. O., & Afolabi, F. (2010). Analysis of science process skills in West African senior secondary school certificate physics practical examinations in Nigeria. *American-Eurasian Journal of Scientific Research*, *5*(4), 234-240.

Akintola, D. A. (2018). The status of biology in Nigerian secondary school curriculum: Implications for scientific literate society. ResearchGate https://www.researchgate.net/publication/329753379_THE_STATUS_OF_BIOLOGY_IN_NIGERIAN_SECONDARY_SCHOOL_CURRICULUM_IMPLICATIONS_FOR_SCIENTIFIC_LITERATE_SOCIETY

Akintoye, A. (2015). Developing theoretical and conceptual frameworks. In *EDMIC research workshop*. Ile-Ife: Faculty of Environmental Design and Management, Obafemi Awolowo University, Ile-Ife, Nigeria.

Akpan, B. B. (2008). *Nigeria and the future of science education*. Oluseyi Press Ltd.

Akuma, F. V., & Callaghan, R. (2019). Teaching practices linked to the implementation of inquiry-based practical work in certain science classrooms. *Journal of research in science teaching*, *56*(1), 64-90.

Alake-Tuenter, E., Biemans, H. J., Tobi, H., Wals, A. E., Oosterheert, I., & Mulder, M. (2012). Inquiry-based science education competencies of primary school teachers: A literature study and critical review of the American National Science Education Standards. *International Journal of Science Education*, *34*(17), 2609-2640.

Alatas, F., & Fachrunisa, Z. (2018). An Effective of Pogil with Virtual Laboratory in Improving Science Process Skills and Attitudes: Simple Harmonic Motion Concept. *EDUSAINS, 10*(2), 327–334.

Alkan, F. (2016). Experiential learning: Its effects on achievement and scientific process skills. *Journal of Turkish Science Education*, *13*(2), 15-26.

Allen, M. ed., (2017). *The SAGE encyclopedia of communication research methods*. SAGE publications.

Al-Rabaani, A. (2014). The acquisition of science process skills by Omani's pre-service social studies teachers. *European Journal of Educational Studies*, *6*(1), 13-19.

Al-Rawi, I. (2013). Teaching methodology and its effects on quality learning. *Journal of Education and Practice*, *4*(6), 100-105.

Altheide, D. L., & Johnson, J. M. (2011). Reflections on interpretive adequacy in qualitative research. *The SAGE handbook of qualitative research*, *4*, 581-594.

Amran, M. M. (2017). Peningkatan hasil belajar dengan menggunakan media KIT IPA di SD Negeri Mapala Makassar. *Jurnal Office, 3*(1), 67-70.Andrade, C. (2021). The inconvenient truth about convenience and purposive samples. *Indian Journal of Psychological Medicine, 43*(1), 86-88.

Ango, M. L. (2002). Mastery of science process skills and their effective use in teaching science: An educology of science education in the Nigerian context. *Online Submission, 16*(1), 11-30.

Arain, M., Campbell, M. J., Cooper, C. L., & Lancaster, G. A. (2010). What is a pilot or

Arkın, İ. E. (2013). *English-medium instruction in higher education: A case study in a Turkish university context* (Doctoral dissertation, Eastern Mediterranean University (EMU)).

Aydin Ceran, S., & Esen, S. (2022). Improving the science process skills and science literacy of primary school preservice teachers with different parental education levels. *Educational Policy Analysis and Strategic Research, 17*(4), 209-232.

Aydoğdu, B. (2015). The investigation of science process skills of science teachers in terms of some variables. *Educational Research and Reviews, 10*(5), 582-594.

Aydoğdu, B., Tatar, N., Yıldız-Feyzioğlu, E., & Buldur, S. (2012). Developing a science process skills scale for elementary students. *Journal of Theoretical Educational Science, 5*(3), 292-311.

Azimi, A., Rusilowati, A., & Sulhadi, S. (2017). Pengembangan media pembelajaran IPA berbasis literasi sains untuk siswa sekolah dasar. *PSEJ (Pancasakti Science Education Journal, 2*(2), 145-157.

Badmus, O. T., & Omosewo, E. O. (2018). Improving Science Education in Nigeria: The Role of Key Stakeholders. *European Journal of Health and Biology Education*, *7*(1), 11-15.

Bahtiar, B., & Dukomalamo, N. (2019). Basic science process skills of biology laboratory practice: improving through discovery learning. *Biosfer: Jurnal Pendidikan Biologi*, *12*(1), 83-93.

Baldwin, K., & Wilson, A. (2017). Acting like rain: Pre-K students engage in science talk and head outside to build Earth science knowledge and process skills. *National Science Teachers Association*.

Baldwin, M. (2012). Participatory action research. *The SAGE handbook of social work*, 467-481.

Barma, S. (2011). A sociocultural reading of reform in science teaching in a secondary biology class. *Cultural Studies of Science Education*, *6*(3), 635-661.

Bassey, B. A., & Amanso, O. I. (2017). Assessing students' gender, school type and science process skills acquisition of senior secondary schools students in

Calabar education zone, Cross Rivers State. *International Journal of Education and Evaluation*, *3*(4), pp.19-25.

Batiibwe, M. S. K. (2019). Using cultural historical activity theory to understand how emerging technologies can mediate teaching and learning in a mathematics classroom: A review of literature. *Research and Practice in Technology Enhanced Learning, 14*(1), 12.

Baydere, F.K., Ayas, A., & Çalik, M., (2020). Effects of a 5Es learning model on the conceptual understanding and science process skills of pre-service science teachers: The case of gases and gas laws. *Journal of the Serbian Chemical Society*, *85*(4), pp.559-573.

Bayne, G.U., & Scantlebury, K. (2012). Using cogenerative dialogues to expand and extend students' learning. In: Irby, B.J., Brown, G., Lara-Alecio, R., & Jackson, S., (Eds.), *The Handbook of Educational Theories*. Information Age, 237-247.

Baysal, E. A., Yörük, A. O., & Ocak, İ. (2022). Acquiring scientific process and innovative thinking skills for secondary school sixth grade students through digital activities: an action research. *Journal of Science Learning*, *5*(3), 411-430.

Behera, S., & Satyaprakasha, C.V. (2014). Effectiveness of multimedia teaching on process skills in Biology. *International Journal of Informative and Futuristic Research. 1*(8).

Bertram, C., & Christiansen, I. (2014). Understanding research. An introduction to reading research. Pretoria: Van Schaik Publishers.

Bhandari, P. (2020). An introduction to qualitative research. Scribbr. https://www.scribbr.com/methodology/qualitative-research/

Bichi, S. S. (2012). The use of problem solving teaching strategy to teach components of blood and their functions. In D. M. Ngufwan & N. Udofia (Eds.), *You as a living thing – Module 1*. Uyo: MEF Ltd.

Blackler, F. (2009). Cultural-historical activity theory and organization studies. *Learning and Expanding with Activity Theory*, 19-39.

Boddy, C. R. (2016). Sample size for qualitative research. *Qualitative Market Research: An International Journal*, *19*(4), 426-432.

Bondi, S. (2013). Using cogenerative dialogues to improve teaching and learning. *About Campus*, *18*(3), 2-8.

Boss, G. J., & Linder, C. (2016). Navigating the Use of Cogenerative Dialogues: Practical Considerations for Graduate Faculty. *International Journal of Teaching and Learning in Higher Education*, *28*(3), 326-334.

Brydon-Miller, M., & Maguire, P. (2009). Participatory action research: Contributions to the development of practitioner inquiry in education. *Educational Action Research*, *17*(1), 79-93.

Byman, R., Maaranen, K., & Kansanen, P. (2021). Consuming, producing, and justifying: Finnish student teachers' views of research methods. *International Journal of Research & Method in Education*, *44*(3), 319-334.

Canuto, P. P. (2023). Perceptions of primary pre-service teachers in the utilization of plant identification apps as educational tools. *Journal of Baltic Science Education*, *22*(5), 799-812.

Carey, M. A., & Asbury, J.-E. (2016). *Focus group research*. Routledge. https://doi.org/10.4324/9781315428376

Carter, I., Harrington, C., & Ahrendt, S. (2024). An examination of an inquiry-based hybrid online/in-person science methods course. *International Journal of Science Education*, 1-19.

Chabalengula, V. M., Mumba, F., & Mbewe, S. (2012). How pre-service teachers' understand and perform science process skills. *Eurasia Journal of Mathematics, Science and Technology Education*, *8*(3), 167-176.

Charlesworth, R. and Lind, K.K., (2010). Math and science. *Nation Review*, *26*, p.11.

Chavan, R. (2016). Difficulties in teaching biology concepts by science teachers at upper primary level. *Online Submission*, *3*(8), 10-18.

Chavan, R., & Patankar, P. (2018). Perception of biological concepts among higher secondary teachers: A study. *Online Submission*, *7*(23), 144-153.

Chiappetta, E. L. (2014). *Science instruction in the middle and secondary schools: Developing fundamental knowledge and skills*. Prentice Hall.

Chinn, P. W. (2007). Decolonizing methodologies and indigenous knowledge: The role of culture, place and personal experience in professional development. *Journal of Research in Science Teaching*, *44*(9), 1247-1268.

Cigdemoglu, C., & Köseoğlu, F. (2019). Improving science teachers' views about scientific inquiry: reflections from a professional development program aiming to advance science centre-school curricula integration. *Science & Education*, *28*(3-5), 439-469.

Çimer, S. O. (2011). The effect of portfolios on students' learning: student teachers' views. *European Journal of Teacher Education*, *34*(2), 161-176.

Coghlan, D., & Brydon-Miller, M. eds., (2014). *The SAGE encyclopedia of action research*. Sage.

Cohen, A.J., Brauer, M., Burnett, R., Anderson, H.R., Frostad, J., Estep, K., Balakrishnan, K., Brunekreef, B., Dandona, L., Dandona, R., & Feigin, V., (2017). Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *The Lancet*, *389*(10082), 1907-1918.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed.). Routledge

Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge.

Coil, D., Wenderoth, M. P., Cunningham, M., & Dirks, C. (2010). Teaching the process of science: faculty perceptions and an effective methodology. *CBE—Life Sciences Education*, *9*(4), 524-535.

Coombs, H. (2022). Case study research: single or multiple [White paper].

Cresswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed method research*. (2nd ed.). Sage.

Creswell, J. W. (2012). *Qualitative inquiry & research design: Choosing among five approaches (4th ed.).* Sage.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches* (4th ed.). Sage Publications.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: qualitative, quantitative, and mixed methods approaches.* Fifth edition. SAGE.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design:*

Creswell, J.W., (2013). Steps in conducting a scholarly mixed methods study. *DBER Speaker Series.* 48. Face

Cupchik, G. (2001). Constructivist realism: An ontology that encompasses positivist and constructivist approaches to the social sciences. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* (Vol. 2, No. 1).

Dana, N.F. (2016). The relevancy and importance of practitioner research in contemporary times. *Journal of Practitioner Research*, *1*(1), 1.

Darmaji, D., Kurniawan, D.A., & Irdianti, I., (2019). Physics education students' science process skills. *International Journal of Evaluation and Research in Education*, *8*(2), pp.293-298.

Deksissa, T., Liang, L. R., Behera, P., & Harkness, S. J. (2014). Fostering significant learning in sciences. *International Journal for the Scholarship of Teaching and Learning*, *8*(2), 1-25.

Denscombe, M. (2007). *The good research guide for small-scale social projects*. McGraw Hill.

Denscombe, M. (2014). *The good research guide: for small-scale social research projects*. McGraw-Hill Education.

Dey, I., (2003). *Qualitative data analysis: A user-friendly guide for social scientists*. Routledge.

Diani, R., Latifah, S., Jamaluddin, W., Pramesti, A., Susilowati, N. E., & Diansah, I. (2020, February). Improving students' science process skills and critical thinking skills in physics learning through fera learning model with savir approach. In *Journal of Physics: Conference Series* (Vol. 1467, No. 1, p. 012045). IOP Publishing.

Dillashaw, F. G., & Okey, J. R. (1980). A test of the integrated science process skills for secondary science students.

Djamahar, R., Ristanto, R. H., Sartono, N., Ichsan, I. Z., Darmawan, E., & Muhlisin, A. (2019, June). Empowering student's metacognitive skill through cirsa learning. *In Journal of Physics: Conference Series, 1227, 1*, 012001. IOP Publishing.

Dogan, I., & Kunt, H. (2016). Determination of prospective preschool teachers' science process skills. *Journal of European Education*, *6*(1), 8-18.

Doyle, S. (2007). Member checking with older women: A framework for negotiating meaning. *Health Care for Women International, 28*(10), 888-908.

Dudovskiy, J. (2019). Data Analysis. Business research methodology. https://research-methodology.net/research-methods/data-analysis/qualitative-data-analysis/

Duran, M., & Dökme, I. (2016). The effect of the inquiry-based learning approach on student's critical-thinking skills. *Eurasia Journal of Mathematics Science and Technology Education, 12*(12).

Durmaz, H., & Mutlu, S. (2017). The effect of an instructional intervention on elementary students' science process skills. *The Journal of Educational Research*, *110*(4), 433-445.

Duruk, U., Akgün, A., Dogan, C., & Gülsuyu, F. (2017). Examining the learning outcomes included in the Turkish science curriculum in terms of science process skills: a document analysis with standards-based assessment. *International Journal of Environmental and Science Education, 12*(2), 117-142.

Dworkin, S. L. (2012). Sample size policy for qualitative studies using in-depth interviews. *Archives of Sexual Behavior, 41*(6), 1319–1320.

Ebenezer, J., Kaya, O. N., & Ebenezer, D. L. (2011). Engaging students in environmental research projects: Perceptions of fluency with innovative technologies and levels of scientific inquiry abilities. *Journal of Research in Science Teaching*, *48*(1), 94-116.

Eckerdal, J. R., & Sundin, O. (2015). Relocating the owl of wisdom: Encyclopaedias in a life-historical perspective. *Nordisk Tidsskrift for Informationsvidenskab og Kulturformidling*, *4*(3), 21-34.

Ediyanto, E., Atika, I., Hayashida, M., & Kawai, N. (2017). A literature study of science process skill toward deaf and hard of hearing students. In *1st Annual International Conference on Mathematics, Science, and Education* (ICoMSE 2017) (pp. 190-195). Atlantis Press.

Egbunonu, R. N., & Ugbaja, C. (2012). Biology teachers' perception of the factors affecting the effective implementation of the biology curriculum. In O. S. Abonyi (Ed.), *Proceedings of the 52nd Annual Conference of the Science Teachers Association of Nigeria* (pp. 235-242).

Ekici, M., & Erdem, M. (2020). Developing science process skills through mobile scientific inquiry. *Thinking Skills and Creativity,* 36. https://doi.org/10.1016/j.tsc.2020.100658

Emereole, H. U. (2009). Learners' and teachers' conceptual knowledge of science processes: The case of Botswana. *International Journal of Science and Mathematics Education, 7*, 1033-1056.

Enger, S. K., & Yager, R. E. (1998). *The iowa assessment handbook* (pp. 5-106). University of Iowa Science Education Center.

Engeström, Y. (1987). *Learning by expanding. An activity-theoretical approach to developmental research.* Orienta-Konsultit Oy.

Engeström, Y. (1999). Activity theory and individual and social transformation. *Perspectives on Activity Theory*, *19*(38), 19-30.

Engestrom, Y. (2000). Activity theory as a framework for analyzing and redesigning work. *Ergonomics, 43*(7), 960-974.

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, *14*(1), 133-156.

Engeström, Y. (2011). From design experiments to formative interventions. *Theory Psychology*, *21*(5), 598-628.

Engeström, Y., & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review*, *5*(1), 1-24.

Engeström, Y., Engeström, R., & Kärkkäinen, M. (1995). Polycontextuality and boundary crossing in expert cognition: Learning and problem solving in complex work activities. *Learning and Instruction*.

Engeström, Y., Miettinen, R., & Punamäki, R. L. (Eds.). (1999). *Perspectives on activity theory*. Cambridge University Press.

Erinosho, S. Y. (2013). How do students perceive the difficulty of physics in secondary school? An exploratory study in Nigeria. *International Journal for Cross-disciplinary Subjects in Education (IJCDSE)*, *3*(3), 1510-1515.

Erkol, S., & Ugulu, I. (2014). Examining biology teachers candidates' scientific process skill levels and comparing these levels in terms of various variables. *Procedia-Social and Behavioral Sciences, 116*, 4742-4747.

Ernawati, T. R. I., Sumiono, B., & Madduppa, H. (2017). Reproductive ecology, spawning potential, and breeding season of blue swimming crab (Portunidae: Portunus pelagicus) in Java Sea, Indonesia. *Biodiversitas Journal of Biological Diversity, 18*(4), 1705-1713.

Espinosa, A. A., Monterola, S. L. C., & Punzalan, A. E. (2013). Career-oriented performance tasks in chemistry: Effects on students' critical thinking skills. *Education Research International,* 2013.

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics, 5*(1), 1-4.

Fan, X., & Geelan, D. (2013). Enhancing students' scientific literacy in science education using interactive simulations: A critical literature review. *Journal of Computers in Mathematics and Science Teaching*, *32*(2), 125-171.

feasibility study? A Review of Current Practice and Editorial Policy. *BMC*

Federal Ministry of Education (FME, 2008). *Teachers' handbook for the 9-year basic education curriculum: Primary and junior secondary school levels*. NERDC Press.

Federal Republic of Nigeria (2004). *National policy on education*. NERDC Press.

Federal Republic of Nigeria. (2013). *National policy on education* (5th ed). NERDC Press.

Ferreira, L. B. M. (2004). *The role of a science story, activities, and dialogue modeled on philosophy for children in teaching basic science process skills to fifth graders*. Montclair State University.

Fleer, M. (2009). Supporting scientific conceptual consciousness or learning in ‘a roundabout way’in play-based contexts. *International Journal of Science Education, 31*(8), 1069-1089.

Flick, U. (2014). Mapping the field. *The SAGE handbook of qualitative data analysis*, 1-18.

Foot, K. A. (2013). Analyzing evolving social work practices via cultural-historical activity theory: Examples from the HUSK Project. In *Workshop of the HUSK Work Group on Evidence-informed Human Service Practice, School of Social Welfare, University of California.*

Foot, K. A. (2014). Cultural-historical activity theory: Exploring a theory to inform practice and research. *Journal of Human Behavior in the Social Environment*, *24*(3), 329-347.

Foot, K., & Groleau, C. (2011). Contradictions, transitions, and materiality in organizing processes: An activity theory perspective. *First Monday*.

Fugarasti, H., Ramli, M., & Muzzazinah, M. (2019, December). Undergraduate students’ science process skills: A systematic review. In *AIP Conference Proceedings* (Vol. 2194, No. 1). AIP Publishing.

Gezer, S. U. (2015). A case study on preservice science teachers’ laboratory usage self-efficacy and scientific process skills. *Procedia-Social and Behavioral Sciences, 174*, 1158-1165.

Ghumdia, A. A. (2016). Effects of inquiry-based teaching strategy on students’ science process skills acquisition in some selected biology concepts in secondary schools in Borno State. *International Journal of Scientific Research, 1*(2), 96-106.

Gibbs, G. R. (2012). Different approaches to coding. *Sociological Methodology*, *42*(1), 82-84.

Gläser, J., & Laudel, G. (2013). Life with and without coding: Two methods for early-stage data analysis. In *Qualitative Research Aiming at Causal Explanations, Forum: Social qualitative research*,14.

Granell, C., Kamilaris, A., Kotsev, A., Ostermann, F.O. & Trilles, S. (2020). Internet of things. *Manual of Digital Eart,* (pp. 387-423).

Grant, C., & Osanloo, A. (2014). Understanding, selecting, and integrating a theoretical framework in dissertation research: Creating the blueprint for your "house". *Administrative Issues Journal, 4*(2), 4.

Gretschel, P., Ramugondo, E. L., & Galvaan, R. (2015). An introduction to cultural historical activity theory as a theoretical lens for understanding how occupational therapists design interventions for persons living in low-income conditions in South Africa. *South African Journal of Occupational Therapy*, *45*(1), 51-55.

Grin, J., Rotmans, J., & Schot, J. (2010). *Transitions to sustainable development: new directions in the study of long term transformative change*. Routledge.

Guevara, C. A. (2015). Science process skills development through innovations in science teaching. *Research Journal of Educational Sciences*, *2321*, 0508.

Gultepe, N. (2016). High school science teachers' views on science process skills. *International Journal of Environmental and Science Education*, *11*(5), 779-800.

Gunawan, G., Harjono, A., Hermansyah, & Herayanti, L. (2019). Guided inquiry model through the virtual laboratory enhances students' science process skills on heat concepts. *Jurnal Cakrawala Pendidikan,* *38*(2). https://doi.org/10.21831/cp.v38i2.23345

Gürses, A., Çetinkaya, S., Doğar, Ç., & Şahin, E. (2015). Determination of levels of use of basic process skills of high school students. *Procedia-Social and Behavioral Sciences*, 191, 644-650.

Hacieminoglu, E. (2016). Elementary school students' attitude toward science and related variables. *International Journal of Environmental and Science Education, 11*(2), 35-52.

Hafizan, E., Halim, L., & Meerah, T. S. (2012). Perception, conceptual knowledge and competency level of integrated science process skill towards planning a professional enhancement programme. *Sains Malaysiana, 41*(7), 921-930.

Hall, A., & Miro, D. (2016). A study of student engagement in project-based learning across multiple approaches to STEM education programs. *School Science and Mathematics*, *116*(6), 310-319.

Handayani, G., Adisyahputra, A. and Indrayanti, R. (2018). Correlation between integrated science process skills, and ability to read comprehension to scientific literacy in biology teachers students. *Biosfer: Jurnal Pendidikan Biologi,* 11(1), 22-32.

Harahap, F., Nasution, N.E.A. and Manurung, B. (2019). The effect of blended learning on student's learning achievement and science process skills in plant tissue culture course. *International Journal of Instruction, 12*(1), 521-538.

Harlen, W. (2010). The Royal Society's report on primary school science. *Primary Science, 115*, 25-27.

Hayes, N., O'Toole, L., & Halpenny, A. M. (2022). *Introducing Bronfenbrenner: A guide for practitioners and students in early years education*. Taylor & Francis.

Hebrio, C. S. (2013). *Attitude, learning styles, and laboratory skills of College of Arts and Sciences students and their relation to performance in general biology* (Master's thesis). Laguna State Polytechnic University, San Pablo City, Laguna.

Hernawati, D., Amin, M., Al Muhdhar, M.H.I., & Indriwati, S.E. (2019). Science literacy skills through the experience of project activities with assisted local potential based learning materials. *JPBI (Jurnal Pendidikan Biologi Indonesia), 5*(1), 159-168.

Hernawati, D., Amin, M., Irawati, M. H., Indriwati, S. E., & Omar, N. (2018). The effectiveness of the scientific approach using encyclopedias as learning materials in improving students' science process skills in science. *Jurnal Pendidikan IPA Indonesia, 7*(3). https://doi.org/10.15294/jpii.v7i3.14459

Heron, J., & Reason, P. (1997). A participatory inquiry paradigm. *Qualitative Inquiry*, *3*(3), 274-294.

Herrmann, K.J. (2013). The impact of cooperative learning on student engagement: Results from an intervention. *Active Learning in Higher Education, 14*(3), 175-187.

Hesse-Biber, S. N., &Leavy, P. (2011). *The practice of qualitative research*. 2nd Ed. Thousand Oaks, CA: Sage.

Hidayah, F. F., Imaduddin, M., Praptaningrum, D., & Ristanti, D. (2020). Cogenerative dialogue of cross-generation educators to improve chemistry teaching quality through technology. *Journal for the Education of Gifted Young Scientists*, *8*(1), 465-487.

Hikmah, N., Yamtinah, S. and Indriyanti, N.Y. (2018). Chemistry teachers' understanding of science process skills in relation to science process skills assessment in chemistry learning. *Journal of Physics: Conference Series 1022*(1), 012038. IOP Publishing.

Hogan, K., & Maglienti, M. (2001). Comparing the epistemological underpinnings of students' and scientists' reasoning about conclusions. *Journal of Research in Science Teaching, 38*(6), 663-687

Hwang, G. J., Tsai, C. C., Chu, H. C., Kinshuk, K., & Chen, C. Y. (2012). A context-aware ubiquitous learning approach to conducting scientific inquiry activities in a science park. *Australasian Journal of Educational Technology*, *28*(5).

Hyman, M., & Sierra, J. (2016). Open- versus close-ended survey questions. *NMSU Business Outlook*, *14*.

Ibiamke, A., & Ajekwe, C. C. (2017). On ensuring rigour in accounting research. *International Journal of Academic Research in Accounting, Finance and Management Sciences*, *7*(3), 157-170.

Idiege, K. J., Nja, C. O., & Ugwu, A. N. (2017). Development of science process skills among Nigerian secondary school science students and pupils: An opinion. *International Journal of Chemistry Education*, *1*(2), 13-21.

Idris, N., Talib, O., & Razali, F. (2022). Strategies in mastering science process skills in science experiments: A systematic literature review. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 155-170.

Igwenagu, C. (2016). Fundamentals of research methodology and data collection. LAP Lambert Academic Publishing.

Ikeobi, I. O. (2010). Beyond the stereotype: Thoughts and reflections on education. *The CIBN Press Limited*.

Illingworth, A., Aranda, K. F., De Goeas, S. M., & Lindley, P. J. (2013). Changing the way that I am: students' experience of educational preparation for advanced nursing roles in the community. *Nurse Education in Practice, 13*(5), 338-343.

Inayah, A. D., Ristanto, R. H., Sigit, D. V., &Miarsyah, M. (2020). Analysis of science process skills in senior high school students. *Universal Journal of Educational Research, 8*(4), 15-22.

Irwanto, E. R., & Prodjosantoso, A. K. (2018). The investigation on university students' science process skills and chemistry attitudes at the laboratory course. In *Asia-Pacific Forum on Science Learning and Teaching*, *19*(2), 1-22).

Irwanto, I. (2023). Improving preservice chemistry teachers' critical thinking and science process skills using research-oriented collaborative inquiry learning. *JOTSE*, *13*(1), 23-35.

Irwanto, I., Rohaeti, E., & Prodjosantoso, A. K. (2018). A survey analysis of pre-service chemistry teachers' critical thinking skills. *MIER Journal of Educational Studies Trends and Practices*, 57-73.

Jack, G.U. (2013). The influence of identified student and school variables on students' science process skills acquisition. *Journal of Education and Practice, 4(*5), 16-22.

Jemal, A., & Bussey, S. (2018). Transformative action: A theoretical framework for breaking new ground. *EJournal of Public Affairs*.

Jeronen, E., Palmberg, I., & Yli-Panula, E. (2016). Teaching methods in biology education and sustainability education including outdoor education for promoting sustainability—A literature review. *Education Sciences*, *7*(1), 1.

Jones, M. L. (2014, June). Living With Contradiction: Cultural Historical Activity Theory as a Theoretical Frame to Study Student Engineering Project Teams. In *2014 ASEE Annual Conference & Exposition* (pp. 24-871).

Juhji, J., & Nuangchalerm, P. (2020). Interaction between science process skills and scientific attitudes of students towards technological pedagogical content knowledge. *Journal for the Education of Gifted Young Scientists, 8*(1), 1-16.

Kabir, S. M. S. (2016). Basic guidelines for research. *An introductory approach for all disciplines*, *4*(2), 168-180.

Kamanga, R., & Alexander, P. M. (2021). Contradictions and strengths in activity systems: Enhancing insights into human activity in IS adoption research. *The Electronic Journal of Information Systems in Developing Countries, 87*(1), e12149.

Kamba, A. H., Giwa, A. A., Libata, I. A., & Wakkala, G. T. (2018). The relationship between science process skills and student attitude toward physics in senior secondary school in Aliero Metropolis. *African Educational Research Journal*, *6*(3), 107-113.

Kampourakis, K., & Reiss, M. J. (2018). *Teaching biology in schools: Global research, issues, and trends*. Routledge.

Karacop, A., & Diken, E. H. (2017). The effects of jigsaw technique based on cooperative learning on prospective science teachers' science process skills. *Journal of Education and Practice, 8*(6), 86-97.

Karamustafaoğlu, S. (2011). Improving the science process skills ability of science student teachers using I diagrams. *International Journal of Physics & Chemistry Education*, *3*(1), 26-38.

Karanasios, S., Riisla, K., & Simeonova, B. (2017). Exploring the use of contradictions in activity theory studies: An interdisciplinary review. Loughborough University. Conference contribution. https://hdl.handle.net/2134/26026

Karar, E. E., & Yenice, N. (2012). The investigation of scientific process skill level of elementary education 8th grade students in view of demographic features. *Procedia-Social and Behavioral Sciences*, *46*, 3885-3889.

Karsli, F., & Şahin, Ç. (2009). Developing worksheet based on science process skills: Factors affecting solubility. In Asia-Pacific Forum on Science Learning and Teaching (Vol. 10, No. 1, pp. 1-12). The Education University of Hong Kong, Department of Science and Environmental Studies.

Karsli, F., & Ayas, A. (2014). Developing a laboratory activity by using 5E learning model on student learning of factors affecting the reaction rate and improving scientific process skills. *Procedia-Social and Behavioral Sciences, 143*, 663-668.

Kartimi, K., & Winarso, W. (2021). Enhancing students' science literacy skills: Implications for scientific approach in elementary school. *Al Ibtida: Jurnal Pendidikan Guru MI, 8*(2), 161-177.

Kassu, J. (2019). *Research design and methodology*.

Kazeni, M. M. M. (2008). Development and validation of a test of integrated science process skills for the further education and training of learners (Doctoral dissertation, University of Pretoria).

Kemmis, S., McTaggart, R., & Nixon, R. (2014). *The action research planner: Doing critical participatory action research*. Springer Science & Business Media.

Kennedy-Clark, S. (2012). Design research and the solo higher degree research student: Strategies to embed trustworthiness and validity into the research design. In 2012 *Joint AARE APERA International Conference* (pp. 1-12).

Klymkowsky, M. W. (2005). Points of view: Content versus process: Is this a fair choice? Can non majors courses lead to biological literacy? Do major courses do any better? *Cell Biology Education*, *4*(3), 196-198.

Koksal, E. A., & Berberoglu, G. (2014). The effect of guided-inquiry instruction on 6th grade Turkish students' achievement, science process skills, and attitudes toward science. *International Journal of Science Education, 36*(1), 66-78.

Krauja, I., Birzina, R., & Cedere, D. (2018). Meaningful Reading Skills for Improvement of Biological Literacy in Primary School. In Rural Environment. Education. Personality (REEP). *Proceedings of the International Scientific Conference (Latvia).* Latvia University of Life Sciences and Technologies.

Kruea-In, C., Kruea-In, N., & Fakcharoenphol, W. (2015). A study of Thai in-service and pre-service science teachers' understanding of science process skills. *Procedia-Social and Behavioral Sciences, 197*, 993-997.

Kruea-In, N., & Thongperm, O. (2014). Teaching of science process skills in Thai contexts: Status, supports and obstacles. *Procedia-Social and Behavioral Sciences,* 141, 1324-1329.

Krueger, R. A., & Casey, M. A. (2002). *Designing and conducting focus group interviews* (Vol. 18).

Kumar, R. (2011). *Research methodology: A step-by-step guide for beginners*. Sage.

Kumar, R. (2014). Research methodology: A step-by-step guide for beginners (4th ed.). Thousand Oaks, CA: SAGE.

Kunga, G. J. (2021). *Effects of inquiry-based science teaching approach on learning outcomes of secondary school Physics students in Kitui County, Kenya* (Doctoral dissertation, Machakos University Press).

Kuutti, K. (1996). Activity theory as a potential framework for human-computer interaction research. In B. Nardi (Ed.), *Context and consciousness: activity theory and human-computer interaction* (pp. 17-44). Cambridge, MA: MIT Press.

Lakin, J. M., & Wallace, C. S. (2015). Assessing dimensions of inquiry practice by middle school science teachers engaged in a professional development program. *Journal of Science Teacher Education*, *26*(2), 139-162.

Leont'ev, A. N. (1978). *Activity, consciousness, and personality.* Prentice-Hall.

Leow, R. P. (2015). *Explicit learning in the L2 classroom: A student-centered approach*. Routledge.

Lester, J. N., Cho, Y., & Lochmiller, C. R. (2020). Learning to do qualitative data analysis: A starting point. *Human Resource Development Review*, *19*(1), 94-106.

Levitt, H. M., Motulsky, S. L., Wertz, F. J., Morrow, S. L., & Ponterotto, J. G. (2017). Recommendations for designing and reviewing qualitative research in psychology: Promoting methodological integrity. *Qualitative Psychology*, *4*(1), 2.

Liamputtong, P. (2011). International students in Australia: Their challenges and implications for university counseling services. *International Journal of Students' Research*, 8-11.

Lin Ting, K. (2014). Effects of Outdoor School Ground Lessons on Students' Science Process Skills and Scientific Curiosity. *Canadian Center of Science and Education, 3*(4).

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage.

Lindrawati, B., & Rohandi. (2015). Keterampilan proses sains calon guru fisika. *Prosiding Pertemuan Ilmiah Jateng*, 15(3), 13-16.

Locke, T., Alcorn, N., & O'Neill, J. (2013). Ethical issues in collaborative action research. *Educational Action Research*, *21*(1), 107-123.

MacDonald, C. (2012). Understanding participatory action research: A qualitative research methodology option. *The Canadian Journal of Action Research*, *13*(2), 34-50.

Mahanal, S., Zubaidah, S., & Setiawan, D. (2020, August). The potential of RICOSRE to enhance university students' science literacy in biology. In *International Conference on Biology, Sciences and Education (ICoBioSE 2019)* (pp. 282-287). Atlantis Press.

Maher, C., Hadfield, M., Hutchings, M., & De Eyto, A. (2018). Ensuring rigor in qualitative data analysis: A design research approach to coding combining NVivo with traditional material methods. *International Journal of Qualitative Methods*, *17*(1), 1609406918786362.

Maheshwari, K. (2013). *Effectiveness of video assisted structured teaching programme on postnatal exercise in terms of knowledge and attitude among postnatal mothers in selected urban area in Bangalore* (Doctoral dissertation, Rajiv Gandhi University of Health Sciences (India)).

Makombe, G. (2017). An expose of the relationship between paradigm, method and design in research. *The Qualitative Report*, *22*(12), 3363.

Malikah, N., Hidayatullah, F., Anitah, S., & Mudjiman, H. (2016). Bifilar cooperative learning model for Hadis memorizing skill in Alquran-Hadis in Madrasah Ibtidaiyah Ponorogo Regency, Indonesia. *International Journal of Education and Research, 4*(11), 211-220.

Manti, S., & Licari, A. (2018). How to obtain informed consent for research. *Breathe, 14*(2), 145-152.

Maranan, V. M. (2017). Basic process skills and attitude toward science: Inputs to an enhanced students' cognitive performance. *Online Submission*. https://files.eric.ed.gov/fulltext/ED579181.pdf

Marshall, B., Cardon, P., Poddar, A., & Fontenot, R. (2013). Does sample size matter in qualitative research? A review of qualitative interviews in IS research. *Journal of Computer Information Systems*, *54*(1), 11-22.

Marshall, C., & Rossman, G.B. (2016). *Designing qualitative research* (6th ed.). Sage.

Matta, R. R. P. (2023). Development of Science Process Skills in Online Mode: A Lesson Study. *International Journal of Scientific and Research Publications*, *13*(3).

Maxwell, J. A. (2016). Expanding the history and range of mixed methods research.

Mbewe, S., Chabalengula, V., & Mumba, F. (2010). Pre-service teachers' familiarity, interest and conceptual understanding of science process skills. *Problems of Education in the 21st Century*, *22*, 76.

McKimm, J., & Forrest, K. (2013). Essential simulation in clinical education. in K Forrest, J McKimm & S Edgar (eds), *Essential simulation in clinical education*. Wiley-Blackwell, Wiley, Chichester, 1-10.

McKimm, J., & Forrest, K. (2013). Essential simulation in clinical education. *Essential Simulation in Clinical Education*, 1-10.

McLeod, S. A. (2018). Questionnaire: definition, examples, design and types. Simplypscychology. *https:///www.simplypsychology.org/questionnaires.html*.

McNamee, S. (2010). Research as social construction: transformative inquiry. *Saúde & Transformação Social/Health & Social Change*, *1*(1), 9-19.

Mensah, E. (2015). Exploring constructivist perspectives in the college classroom. *SAGE Open*, *5*(3), 2158244015596208.

Mertens, D. M. (2010). *Research and evaluation in education and psychology integrating diversity with quantitative, Qualitative, and mixed methods* (3rd ed.). Sage Publications.

Mertens, M. (2015). *Research and evaluation in education and psychology* (4th ed.). Sage Publications.

Mezirow, J. (2018). Transformative learning theory. In *Contemporary theories of learning* (pp. 114-128). Routledge.

Miles, E. (2010). *In-service elementary teachers' familiarity, interest, conceptual knowledge, and performance on science process skills* (Doctoral dissertation, Southern Illinois University).

Miles, R. (2015). Tutorial instruction in science education. *Cypriot Journal of Educational Sciences*, *10*(2), 168-179.

Miller, C. (2017). The persistent effect of temporary affirmative action. American Economic *Journal: Applied Economics, 9*(3), 152-190.

Miller, J. D. (2011). To improve science literacy, researchers should run for school board. *Nature Medicine, 17*(1), 21.

Miller, K. J. (2017). *A Doctor on the clock: Hourly timekeeping and galen's scientific method*. The University of Chicago.

Minstrell, J., & Van Zee, E. H. (2000). Inquiring into inquiry learning and teaching in science. (No Title).

Mirian, O. B. (2023). An assessment of science process skills among science students in River State, Nigeria. *Journal of Advance Research in Applied Science*, *9*(3), 1-5.

Molefe, L., & Aubin, J. B. (2021). Exploring how science process skills blend with the scientific process: Pre-service teachers’ views following fieldwork experience. *South African Journal of Education*, *41*(2), 1-13.

Molefe, L., & Aubin, J. B. (2021). Pre-service teachers' views about ecosystem-based fieldwork in terms of the nature of environmental education, investigations, skills, and processes. *Journal of Baltic Science Education, 20*(4), 622-638.

Morse, J.M., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2002). Verification strategies for establishing reliability and validity in qualitative research. *International Journal of Qualitative Methods*, *1*(2), 13-22.

Movahedzadeh, F. (2011). Improving students’ attitude toward science through blended learning. *Science Education and Civic Engagement, 3*(2), 13-19.

Mulbar, U., & Bahri, A. (2021). Scientific literacy skills of students: Problem of biology teaching in junior high school in South Sulawesi, Indonesia. *International Journal of Instruction*, *14*(3), 847-860.

Mulyeni, T., Jamaris, M. and Supriyati, Y. (2019). Improving basic science process skills through inquiry-based approach in learning science for early elementary students. *Journal of Turkish Science Education, 16*(2), 187-201.

Mumba, F., Miles, E., & Chabalengula, V. (2019). Elementary education in-service teachers’ familiarity, interest, conceptual knowledge and performance on science process skills. *Journal of STEM Teacher Education*, *53*(2), 3

Murphy, A. F. (2012). *Sustaining inquiry-based teaching methods in the middle school science classroom*. The University of Alabama.

Murphy, C., & Carlisle, K. (2008). Situating relational ontology and transformative activist stance within the ‘everyday ’ practice of coteaching and cogenerative dialogue. *Cultural Studies of Science Education*, *3*(2), 493-506.

Nadiah, N., Salleh, S., & Laxman, K. (2021). The impact of video-based Predict-Observe-Explain (POE) on secondary school students' scientific literacy. *International Journal on E-Learning*, *20*(3), 295-321.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Neuman, W. L. (2014). *Social research methods: qualitative and quantitative approaches*. Pearson.

Newby, P. (2010). *Research methods for education*. Pearson Education.

Nguyen, N., Williams, J., & Nguyen, T. (2012). The use of ICT in teaching tertiary physics: Technology and pedagogy. In *Asia-Pacific Forum on Science Learning & Teaching 13*, 2.

Nursalam, L. O., Sailan, Z., Hakim, A. R., Rosadi, A., Suhardi, M., Asyş_ari, M., ... & Bilad, M. R. (2022). Exploring pre-service teacher' views of science process skills. In *Journal of Physics: Conference Series* (Vol. 2165, No. 1, p. 012012). IOP Publishing.

Nwagbo, C., & Chukelu, U. C. (2011). Effects of biology practical activities on students' process skill acquisition. *Journal of Science Teachers Association of Nigeria*, *46*(1), 58-70.

Nwosu, A. C. (2010). Causes of poor academic performance of chemistry students. *Nigerian Journal of Issues in Science Education*, *1*(1), 35-37.

Nyakiti, C. Mwangi, J., & Koyier, C. (2010) *Mastering PTE science.* Oxford University Press.

Nzelum, V. N. (2010). Mechanisms of transmission of information along the neurons: A practical approach to reflex action. In *A paper presented as STAN Biology panel workshop model of girls secondary schools, Rumeme*.

O'Leary, Z. (2014). *The essential guide to doing your research project* (2nd ed.). Sage.

Obialor, C. O, Osuafor, A. M., & Nnadi E. I (2017). Effect of project work on secondary school students' science process skills acquisition in biology. *Journal of Research in National Development, 15*(1) 348-354.

Obialor, C. O. (2016). *Effect of project work on students' science process skills acquisition and achievement in secondary school biology.* (Master's thesis, Nnamdi Azikiwe University Awka).

Ojebiyi, O. A., & Sunday, F. L. (2014). A historical survey of the development of science and technology education in Nigeria. *Academic Journal of Interdisciplinary Studies*, *3*(6), 285-285.

Okolie, U. C., Nwajiuba, C. A., Eneje, B., Binuomote, M. O., Ehiobuche, C., & Hack-Polay, D. (2021). A critical perspective on industry involvement in higher education learning: Enhancing graduates' knowledge and skills for job creation in Nigeria. *Industry and Higher Education*, *35*(1), 61-72.

Oladejo, M. A., Olosunde, G. R., Ojebisi, A. O., & Isola, O. M. (2011). Instructional materials and students' academic achievement in physics: Some policy implications. *European Journal of Humanities and Social Sciences*, *2*(1).

Oliveira, I., Tinoca, L., & Pereira, A. (2011). Online group work patterns: How to promote a successful collaboration. *Computers & Education, 57*(1), 1348-1357.

Omigbodun, O. O., Adediran, K. I., Akinyemi, J. O., Omigbodun, A. O., Adedokun, B. O., & Esan, O. (2010). Gender and rural-urban differences in the nutritional status of in-school adolescents in south-western Nigeria. *Journal of Biosocial Science*, *42*(5), 653-676.

Omoifo, C. N. (2012). Dance of the limits reversing the trend in science education in Nigeria. *Inaugural Lecture Series*, *124*, 13-36.

Omona, J. (2013). Sampling in qualitative research: Improving the quality of research outcomes in higher education. *Makerere Journal of Higher Education*, *4*(2), 169-185.

Omosewo, E. O. (2009). Views of physics teachers on the need to train and retrain Physics teachers in Nigeria. *African Research Review*, *3*(1).

Onel, A., & Firat Durdukoca, S. (2019). Identifying the predictive power of biological literacy and attitudes toward biology in academic achievement in high school students. *International Online Journal of Educational Sciences*, *11*(2), 214-228)

Ong'amo, B. L., Ondigi, S. R., & Omariba, A. (2017). Effect of utilization of biology teaching and learning resources on students' academic performance in secondary schools in Siaya District-Kenya. *International Journal of Education and Research, 5*(1), 253-272.

Ongowo, R. O., & Indoshi, F. C. (2013). Science process skills in the Kenya certificate of secondary education biology practical examinations. *Creative Education*, *4*(11), 713.

Opara, J. A., & Oguzor, N. S. (2011). Inquiry instructional method and the school science curriculum. *Current Research Journal of Social Sciences, 3*(3), 188-198.

Opateye, J. A. (2012). Developing and assessing science and technology process skills (STPSs) in Nigerian universal basic education environment. *Journal of Educational and Social Research, 2*(8), 34-42.

Opulencia, L. M. (2011). *Correlates of science achievement among grade-VI pupils in selected elementary schools San Francisco District, Division of San Pablo City*. Laguna State Polytechnic University.

Orlich, D. C., Harder, R. J., Callahan, R. C., Trevisan, M. S., & Brown, A. H. (2010). Teaching Strategies-Guide to Effective Instruction. *Wadsworth Engage Learning*, *381*(13), 978-1.

Osarenren-Osaghae, R. I., & Irabor, Q. O. (2018). Educational policies and programmes implementations: A case study of education funding, universal basic education (UBE) and teacher education. *International Journal of Educational Administration and Policy Studies*, *10*(8), 91-102.

Ospina, S., El Hadidy, W., & Hofmann-Pinilla, A. (2008). Cooperative inquiry for learning and connectedness. *Action Learning: Research and Practice*, *5*(2), 131-147.

Owolabi, T. (2012). Characteristics of professional development and impact of training on science teachers" classroom practices. *Universal Journal of Education and General Studies*, *1*(5), 119-125.

Oyelola, S. O. (2015). Lapses in Education Policy Formulation Processes in Nigeria: Implications for the Standard of Education. *Journal of Education and Practice*, *6*(29), 195-202.

Özer, F., & Sarıbaş, D. (2023). Exploring pre-service science teachers' understanding of scientific inquiry and scientific practices through a laboratory course. *Science & Education*, *32*(3), 787-820.

Özgelen, S. (2012). Students' science process skills within a cognitive domain framework. *Eurasia Journal of Mathematics, Science and Technology Education*, *8*(4), 283-292.

Padgett, D. (2017). Q*ualitative methods in social work research*. Sage Publications.

Pain, R., Whitman, G., & Milledge, D. (2011). Participatory action research toolkit: An introduction to using PAR as an approach to learning. *Research and Action.*

Panoy, B. R. P. (2013). *Differentiated strategy in teaching and skills development of pupils in elementary science. (*Master's Thesis, Laguna State Polytechnic University).

Park, C., & Martin, S. N. (2018). Improving science teaching and learning for new teachers and diverse learners using participatory action research and Ccogenerative dialogue. *Journal of the Korean Association for Science Education*, *38*(2), 97-112.

Patton, M. Q. (2002). Two decades of developments in qualitative inquiry: A personal, experiential perspective. *Qualitative Social Work*, *1*(3), 261-283.

Patton, M. Q. (2015). Qualitative research and methods: Integrating theory and practice. *Sage*

Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). Artificial intelligence in education: Challenges and opportunities for sustainable development.

Pine, G. J. (2009). Teacher action research: Collaborative, participatory, and democratic
inquiry. *Teacher action research: Building knowledge democracies*, 29-62.

Polit, D. F., & Beck, C. T. (2014). *Essentials of nursing research: Appraising evidence for nursing practice* (8th ed.). Philadelphia, PA: Wolters Kluwer/Lippincott Williams & Wilkins.

Popping, R., (2015). Analyzing open-ended questions by means of text analysis procedures. *Bulletin of Sociological Methodology/Bulletin de Méthodologie Sociologique, 128*(1), 23-39.

Pozzebon, M. (2018). From aseptic distance to passionate engagement: Reflections about the place and value of participatory inquiry. *RAUSP Management Journal*, *53*(2), 280-284.

Prayitno, B. A., Corebima, D., Susilo, H., Zubaidah, S., & Ramli, M. (2017). Closing the science process skills gap between students with high- and low-level academic achievement. *Journal of Baltic Science Education, 16*(2), 266.

Punch, J. P., & Oancea, A. (2014). *Introduction to research methods in education.* Sage Publications.

Punch, K. F. (2013). *Introduction to social research: Quantitative and qualitative approaches*. Sage.

Raj, R. G., & Devi, S. N. (2014). Science process skills and achievement in science among high school students. *Scholarly Research Journal for Interdisciplinary Studies, 2*(15), 2435-2443.

Rambuda, A. M. (2006). *A study of the application of science process skills to the teaching of geography in secondary schools in the Free State Province* (Doctoral dissertation, University of Pretoria).

Ramugondo, E. L., & Kronenberg, F. (2015). Explaining collective occupations from a human relations perspective: bridging the individual-collective dichotomy. *Journal of Occupational Science, 22*(1), 3-16.

Rauf, R. A. A., Rasul, M. S., Mansor, A. N., Othman, Z., & Lyndon, N. (2013). Inculcation of science process skills in a science classroom. *Asian Social Science, 9*(8), 47.

Ravitch, S. M., & Carl, N. M. (2019). *Qualitative research: Bridging the conceptual, theoretical, and methodological.* Sage Publications.

Reason, P., & Bradbury, H. (Eds.). (2001). *Handbook of action research: Participative inquiry and practice*. Sage.

Research Methodology, *10*(1), 1-7.

Resnik, D. B. (2020). *What Is Ethics in Research & Why Is It Important?* National Institute of Environmental Health Sciences. https://www.niehs.nih.gov/research/resources/bioethics/whatis

Rini, R. (2017). Fake news and partisan epistemology. *Kennedy Institute of Ethics Journal, 27*(2), E-43.

Rosenthal, R., & Rosnow, R. L. (2009). *Artifacts in behavioral research: Robert Rosenthal and Ralph L. Rosnow's classic books*. Oxford University Press.

Rotowa, O. O., Olujimi, J. A. B., Omole, F. K., & Olajuyigbe, A. E. (2015). Socioeconomic factors affecting household's sanitation preferences in Akure, Nigeria. *Eur. Int. J. Sci. Technol.*, *4*, 183-194.

Roulston, K., & Shelton, S. A. (2015). Reconceptualizing bias in teaching qualitative research methods. *Qualitative Inquiry*, *21*(4), 332-342.

Ryen, A. (2011). Ethics and qualitative research. *Qualitative Research, 3*, 416-238.

Safaah, E. S., Muslim, M., & Liliawati, W. (2017, September). Teaching science process skills by using the 5-stage learning cycle in junior high school. In *Journal of Physics: Conference Series*, Vol. 895(1), 012106. IOP Publishing.

Sampson, J., & Yeomans, R. (2010) Analysing the role of mentors: in Andrew Pollard, (Ed.) *Reading for reflective teaching*. New York Continuum.

Santos, M. D., & David, A. P. (2017). Self-and teacher-assessment of science process skills. *The Normal Lights, 11*(1).

Saracoglu, S., Boyuk, U., & Tanik, N. (2012). Birleştirilmiş ve bağımsız sınıflarda öğrenim gören ilköğretim öğrencilerinin bilimsel süreç beceri düzeyleri. *Journal of Turkish Science Education*, *9*(1), 83-100.

Schoonenboom, J., & Johnson, R. B. (2017). How to construct a mixed methods research design. *Kolner Zeitschrift fur Soziologie und Sozialpsychologie*, *69*(Suppl 2), 107.

Schwartz, L., Adler, I., Madjar, N., & Zion, M. (2021). Rising to the challenge: The effect of individual and social metacognitive scaffolds on students' expressions of autonomy and competence throughout an inquiry process. *Journal of Science Education and Technology*, *30*, 582-593.

Semilarski, H., & Laius, A. (2021). Exploring biological literacy: A systematic literature review of biological literacy. *European Journal of Educational Research, 10*(3), 1181-1197.

Shahali, E. H. M., Halim, L., Rasul, S., Osman, K., Ikhsan, Z., & Rahim, F. (2015). Bitara-STEMTM training of trainers' programme: impact on trainers' knowledge, beliefs, attitudes and efficacy towards integrated stem teaching. *Journal of Baltic Science Education, 14*(1), 85.

Shahali, E. H., Halim, L., Treagust, D. F., Won, M., & Chandrasegaran, A. L. (2017). Primary school teachers' understanding of science process skills in relation to their teaching qualifications and teaching experience. *Research in Science Education*, *47*(2), 257-281.

Sholikah, M. A., Muhyadi, M., Indartono, S., Kenzhaliyev, O. B., & Kassymova, G. K. (2021). Self-efficacy and student achievement for enhancing career readiness: The mediation of career maturity. *Jurnal Pendidikan Teknologi dan Kejuruan, 27*(1), 15-25.

Shope III, R. E. (2006). *Teaching science for conceptual change: Toward a proposed taxonomy of diagnostic teaching strategies to gauge students' personal science conceptions*. University of Southern California.

Silay, I., & Çelik, P. (2013). Evaluation of scientific process skills of teacher candidates. *Procedia-Social and Behavioral Sciences, 106*, 1122-1130.

Sim, J., & Waterfield, J. (2019). Focus group methodology: some ethical challenges. *Quality & Quantity*, *53*(6), 3003-3022.

Sinaga, D. J. A. (2021, November). The influence of problem based learning model and critical thinking skills on students science process skills. In *6th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2021)* (pp. 191-197). Atlantis Press.

Sokhanvar, Z., & Salehi, K. (2018). Participatory action research to promote educational quality: A literature review. *Research & Reviews: Journal of Educational Studies*, *4*(2), 23-34.

Southern Utah University. https://doi.org/10.5281/zenodo.7604301.

Stahl, N. A., & King, J. R. (2020). Expanding approaches for research: Understanding and using trustworthiness in qualitative research. *Journal of Developmental Education*, *44*(1), 26-28.

Stith, I., & Roth, W. M. (2010). Teaching as mediation: The cogenerative dialogue and ethical understandings. *Teaching and Teacher Education*, *26*(2), 363-370.

Sugiyono, T., Sulistyorini, S., & Rusilowati, A. (2017). Pengembangan perangkat pembelajaran IPA bervisi sets dengan metode otdoor learning untuk menanamkan nilai karakter bangsa. *Journal of Primary Education*, 6(1), 8-20.

Sukarno, A. P., Hamidah, I., Widodo, A., & Budhi, J. S. (2013). The analysis of science teacher barriers in implementing of science process skills (SPS) teaching approach at junior high school and it's solutions. *Journal of Education and Practice*, *4*(27), 185-190.

Suryanti, S., Ibrahim, M., & Lede, N. S. (2018). Process skills approach to develop primary students' scientific literacy: A case study with low achieving students on water cycle. *IOP Conference Series: Materials Science and Engineering*, *296*(1), 012030. https://doi.org/10.1088/1757-899x/296/1/012030

Susanti, R., & Anwar, Y. (2018, April). Profile of science process skills of preservice biology teacher in general biology course. *Journal of Physics Conference Series*, *1006*(1), 012003).

Suwono, H. (2016). School literary movement in Indonesia: Challenges for scientific literacy. In *International Conference on Education (ICE2) 2018: Education and Innovation in Science in the Digital Era* (pp. 309-317).

Suwono, H., Pratiwi, H. E., Susanto, H., & Susilo, H. (2017). Enhancement of students' biological literacy and critical thinking of biology through socio-biological case-based learning. *Jurnal Pendidikan IPA Indonesia*, *6*(2), 213-220.

Tahir, J. (2017). An Analysis of science process skills of pre-service biology teachers in solving plants physiology problems. *In 2016, International Conference On Education* (pp. 454 – 457).

Taylor, C., & Gibbs, G. R. (2010). How and what to code. *Online QDA Web Site*, *19*.

Testa, I., Zappia, A., & Galano, S. (2017). Improving students’ views about scientific inquiry through explicit teaching: a rasch-based analysis. Paper presented at European Science Education Research Association, ESERA.

Tilakaratne, C. T. K., & Ekanayake, T. M. S. S. K. Y. (2017). Achievement level of science process skills of junior secondary students: Based on a sample of grade six and seven students from Sri Lanka. *International Journal of Environmental & Science Education*, *12*(9), 2089-2108.

Tobin, K. (2014). Twenty questions about cogenerative dialogues. In *transforming urban education* (pp. 181-190). SensePublishers.

Triwiyonoa, T., & Pandac, F. M. (2019). Learning force topics with science process skills approach and using guided experiment methods to improve students' understanding of the concepts. *Learning*, *5*(6), 1011-1020.

Trust, T. (2017). Motivation, empowerment, and innovation: Teachers' beliefs about how participating in the Edmodo math subject community shapes teaching and learning. *Journal of Research on Technology in Education*, *49*(1-2), 16-30.

Tsai, C. C., Chuang, S. C., Liang, J. C., & Tsai, M. J. (2011). Self-efficacy in Internet-based learning environments: A literature review. *Journal of Educational Technology & Society*, *14*(4), 222-240.

Türkmen, H. & Kandemir, E. M. (2011). Öğretmenlerin bilimsel süreç becerileri öğrenme alanı algıları üzerine bir durum çalışması [A case study on teachers' perceptions of science process skills learning area]. *Journal of European Education, 1*(1), 15- 24.

Turkmen, H., & Unver, E. (2018). Comparison of elementary students' images of science teaching for turkish, dutch, scottish, and german science classrooms. *Universal Journal of Educational Research*, *6*(11), 2624-2633.

Ugwanyi, A. A. (2015). *Science process skills acquired by senior secondary school students in Enugu educational zone* (Unpublished Master's Thesis). University of Nigeria.

Ugwuanyi, A. A., & Nwafor, S. C. (2021). Science process skills acquired by senior secondary school chemistry students in qualitative analysis in Enugu Education zone, Nigeria. *UNIZIK Journal of Educational Research and Policy Studies*, *7*, 518-533.

Ungar, S. J. (2010). Seven major misperceptions about the liberal arts. *The Chronicle of Higher Education*, A40-A41.

Uno, G. E., & Bybee, R. W. (1994). Understanding the dimensions of biological literacy. *BioScience*, *44*(8), 553-557.

Valanides, N., & Angeli, C. (2008). Learning and teaching about scientific models with a computer-modeling tool. *Computers in Human Behaviour*, *24*(2), 220-233.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wagino, W., Ambiyar, A., Wakhinuddin, S., Suhendar, S., & Nanda, I. (2022). Meta-analysis: the effectiveness of project-based learning model on learning outcomes. *VANOS Journal of Mechanical Engineering Education, 7*(1).

Wahyuni, S., Indrawati, I., Sudarti, S., & Suana, W. (2017). Developing science process skills and problem-solving abilities based on outdoor learning in junior high school. *Jurnal Pendidikan IPA Indonesia, 6*(1). https://doi.org/10.15294/jpii.v6i1.6849

Walter, M. M. (2009). Participatory action research: Social research methods. *Oxford*.

Wanbugu, P. W., Changeiywo, J. M., & Ndiritu, F. G. (2013). Investigations of experimental cooperative Concept mapping instructional approach on secondary school girls' achievement in physics in Nyeri County, Kenya. *Journal of Education and Practice*, *4*(6), 120-130.

Wendell, K. B., & Rogers, C. (2013). Engineering design-based science, science content performance, and science attitudes in elementary school. *Journal of Engineering Education*, *102*(4), 513-540.

Widdina, S., Rochintaniawati, D., & Rusyati, L. (2018). The profile of students' science process skill in learning human muscle tissue experiment at secondary school. *Journal of Science Learning*, *1*(2), 53-59.

Widyaningsih, D. A. (2020, February). Analysis of science process skills on science learning in primary school. In *3rd International Conference on Learning Innovation and Quality Education (ICLIQE 2019)* (pp. 679-687). Atlantis Press.

Wilson, D., & Conyers, M. (2020). *Developing growth mindsets: Principles and practices for maximizing students' potential*. Ascd.

Wilujeng, I., & Prasetyo, Z. K. (2018). Elaborating indigenous knowledge in the science curriculum for the cultural sustainability. *Journal of Teacher Education for Sustainability, 20*(2), 74-88.

Wright, R. L. (2005). Points of view: content versus process: is this a fair choice? Undergraduate biology courses for nonscientists: toward a lived curriculum. *Cell Biology Education*, *4*(3), 189-196.

Wulf, C. (2019). "From teaching to learning": Characteristics and challenges of a student-centered learning culture. *Inquiry-based learning–Undergraduate research: The German Multidisciplinary Experience*, 47-55.

Yadav, B., & Mishra, S. K. (2013). A Study of the impact of laboratory approach on achievement and process skills in science among Is standard students. *International Journal of Scientific and Research Publications*, *3*(1), 1-6.

Yildirim, B. (2016). An Analyses and meta-synthesis of research on STEM education. *Journal of Education and Practice*, *7*(34), 23-33.

Yildirim, M., Çalik, M., & Özmen, H. (2016). A meta-synthesis of turkish studies in science process skills. *International Journal of Environmental and Science Education*, *11*(14), 6518-6539.

Yilmaz, Y., & Granena, G. (2019). Cognitive individual differences as predictors of improvement and awareness under implicit and explicit feedback conditions. *The Modern Language Journal*, *103*(3), 686-702.

Yin, R. K. (2014). *Case study research: Design and methods*. Los Angeles, CA: Sage

Yliruka, L., & Karvinen-Niinikoski, S. (2013). How can we enhance productivity in social work? Dynamically reflective structures, dialogic leadership and the development of transformative expertise. *Journal of Social Work Practice*, *27*(2), 191-206.

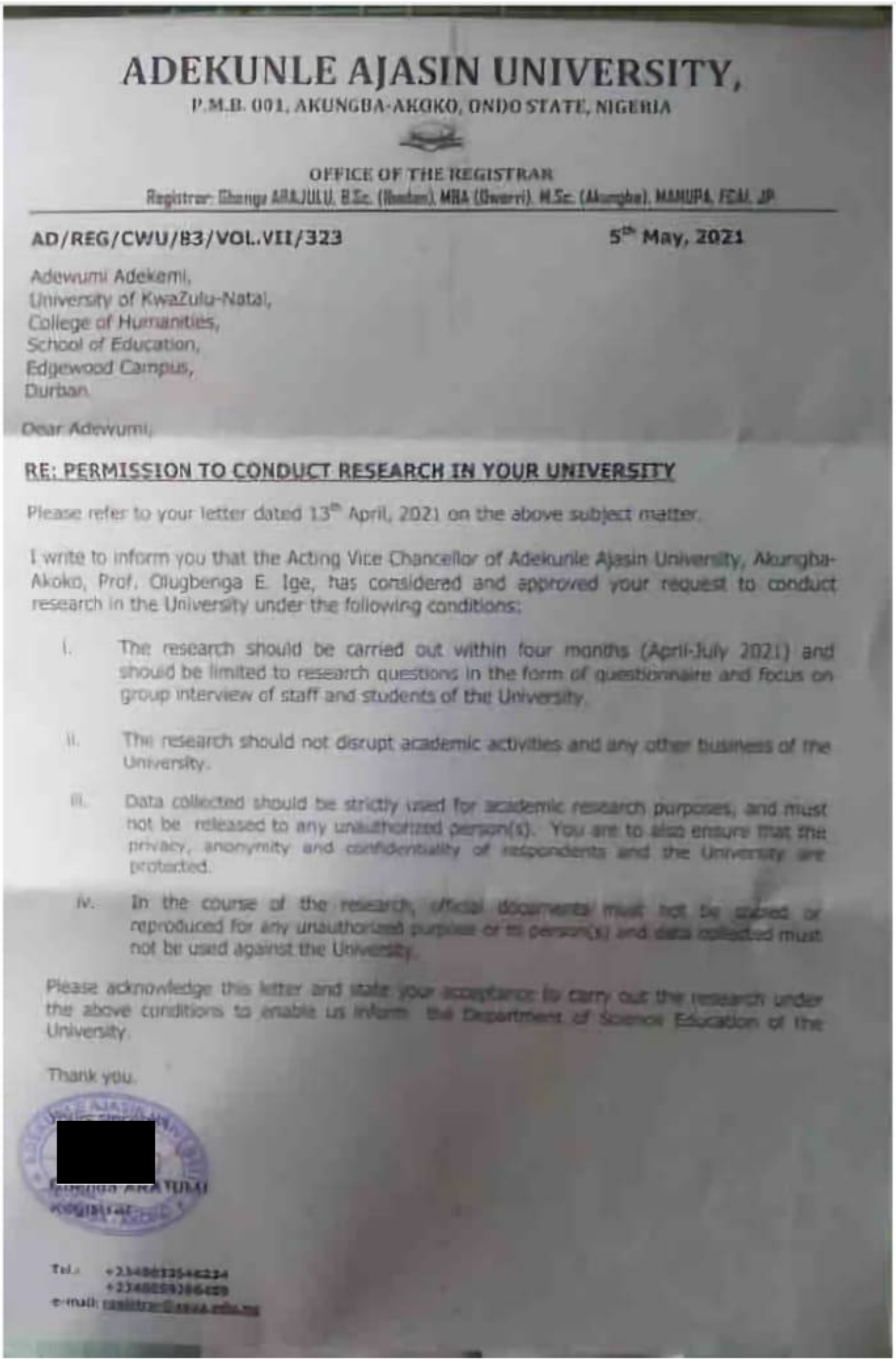
Yumusak, G. K. (2016). Science process skills in science curricula applied in Turkey. *Journal of Education and Practice*, *7*(20), 94-98.

Zeidan, A. (2010). The relationship between grade 11 Palestinian attitudes toward biology and their perceptions of the biology learning environment. *International Journal of Science and Mathematics Education*, *8*(5), 783-800.

Zeidan, A. H., & Jayosi, M. R. (2015). Science process skills and attitudes toward science among palestinian secondary school students. *World Journal of Education*, *5*(1), 13-24.

Appendices

Appendix A – Gatekeeper's Permission Letter



ADEKUNLE AJASIN UNIVERSITY,
P.M.B. 001, AKUNGBA-AKOKO, ONDO STATE, NIGERIA

OFFICE OF THE REGISTRAR
Registrar: Gbenga ARAJULU, B.Sc. (Ibadan), MBA (Owerri), M.Sc. (Akungba), MANUPA, FCAI, JP

AD/REG/CWU/B3/VOL.VII/323 5th May, 2021

Adewumi Adekemi,
University of KwaZulu-Natal,
College of Humanities,
School of Education,
Edgewood Campus,
Durban.

Dear Adewumi,

RE: PERMISSION TO CONDUCT RESEARCH IN YOUR UNIVERSITY

Please refer to your letter dated 13th April, 2021 on the above subject matter.

I write to inform you that the Acting Vice Chancellor of Adekunle Ajasin University, Akungba-Akoko, Prof. Olugbenga E. Ige, has considered and approved your request to conduct research in the University under the following conditions:

i. The research should be carried out within four months (April-July 2021) and should be limited to research questions in the form of questionnaire and focus on group interview of staff and students of the University.

ii. The research should not disrupt academic activities and any other business of the University.

iii. Data collected should be strictly used for academic research purposes, and must not be released to any unauthorized person(s). You are to also ensure that the privacy, anonymity and confidentiality of respondents and the University are protected.

iv. In the course of the research, official documents must not be copied or reproduced for any unauthorized purpose or to person(s) and data collected must not be used against the University.

Please acknowledge this letter and state your acceptance to carry out the research under the above conditions to enable us inform the Department of Science Education of the University.

Thank you.

[redacted]

[illegible]
Registrar

Tel.: [illegible]
[illegible]
e-mail: [illegible]

Appendix B – Ethical Clearance from University of KwaZulu-Natal

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

05 September 2021

Miss Adekemi Oreoluwa Adewumi (219091687)
School Of Education
Edgewood Campus

Dear Miss Adewumi,

Protocol reference number: HSSREC/00003213/2021
Project title: Pre-service teachers' use of science process skills in understanding biological concepts based on plant taxonomy in a Nigerian University.
Degree: PhD

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 04 August 2021 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 05 September 2022.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 8350/4557/3587 **Email:** hssrec@ukzn.ac.za **Website:** http://research.ukzn.ac.za/Research-Ethics

Appendix C – Permission Letter to University

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

The Registrar

Adekunle Ajasin University

Akungba- Akoko

Ondo State

Nigeria

Dear Sir,

PERMISSION TO CONDUCT RESEARCH IN YOUR UNIVERSITY

My name is Adewumi Adekemi, a PhD student at the University of KwaZulu-Natal. I am writing this letter to seek for your permission to conduct my research in your University. The title of my research is: **Exploring pre-service teachers' use of science process skills to understand biological concepts in a Nigerian University.**

The research is to be conducted among 300 level and 400 level pre-service biology teachers in the Department of Science Education, Faculty of Education and also Biology Lecturers. My research will not in any way interrupt the University programmes, focus group interviews and cogenerative dialogue will be conducted among the selected participants after school activities during the participants' leisure time. The data collection for this research will be carried out between January 2021 to March 2021.

This study will contribute to how pre-service teachers use science process skills to understand biology. This study has been reviewed and approved by the ethical committee of the UKZN with approval number ………………. and enclosed here, is a letter from my University authorizing me to conduct the research in your University.

In case of any concerns or questions, you may contact my supervisor at UKZN Dr. Leonard Molefe. His contact details are: Email Molefe@ukzn.ac.za Telephone no: 031 260 3447

Thank you in anticipation.

Yours Sincerely

____

Adewumi Adekemi

University of KwaZulu-Natal

College of Humanities

School of Education

Edgewood Campus

Durban

08139608437

adekemi.adewumi@aaua.edu.ng

Appendix D: Participants' consent letter

The Participant
Adekunle Ajasin University
Akungba-Akoko
Ondo State
Nigeria

Dear participants,

LETTER OF CONSENT

My name is Adewumi Adekemi, a PhD student at the University of KwaZulu-Natal. I am writing this letter to seek for your permission to conduct my research in your University. The title of my research is: **Exploring pre-service teachers' use of science process skills to understand biological concepts in a Nigerian University.**

The purpose of this study is to know if pre-service teachers use science process skills to understand biological concepts and also to find out the pedagogical approaches used by lecturers in teaching biological concepts. By participating in this research I will be able to find out about all these.

Your participation in this study is voluntary and you may withdraw from the study at any time. You also have the option not to participate in the study. Note that participating in this study does not in any way put you at risk. All the information you provide will be kept private and all reports that will be written using the information obtained will also not bear your name. My supervisor and I will be the only ones who will have access to the information you provide. You will be requested to participate in a focus group interview and cogenerative dialogue which will last for about one and a half hours.

This study has been reviewed and approved by the ethical committee of the UKZN with approval number ………………. and enclosed here, is a letter from my University authorizing me to conduct the research in your University.

In case of any concerns or questions, you may contact my supervisor at UKZN Dr. Leonard Molefe. His contact details are: Email Molefe@ukzn.ac.za Telephone no: 031 260 3447.

You can also contact my University research office for any clarification at Govan Mbeki, Westville Campus through this email: HSSREC@ukzn.ac.za

Thank you in anticipation.

Yours Sincerely

[redacted]

Adewumi Adekemi
University of KwaZulu-Natal
College of Humanities
School of Education
Edgewood Campus
Durban
08139608437
adekemi.adewumi@aaua.edu.ng

Declaration

Research topic: Pre-service teachers' use of science process skills in understanding biological concepts based on plant taxonomy in a Nigerian University.

I …………………………………………………………… (Full names of participant) hereby confirm that I understand the consent of this document and the nature of the research project and I consent to participate in this research project.

I understand that:

- My participation in this research is voluntary and I can withdraw at any time with no negative consequences.
- I voluntarily give permission for videos and pictures to be taken and for my voice to be recorded digitally.
- My identity will be kept private.

……………………………..   ……………………………….

Signature of Participant   Date

Appendix E: Questionnaire for Pre-Service Biology Teachers on Science Process Skills

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Dear participant,

The researcher is carrying out a study on pre-service teachers' use of science process skills in understanding biological concepts based on plant taxonomy at a Nigerian University.

You have been selected as one of the participants for the study and this questionnaire seeks to know your conceptual knowledge of science process skills. Your participation will contribute immensely to this study. You are requested to complete the details on the next page in your own writing in the spaces provided.

Information of participants

Year of study: ………..

Define or explain, in your own words, the following science process skills.

CLASSIFYING

……

……

……

……

……

MEASURING

……

……

……

……

……

OPERATIONAL DEFINITION

……

……

……

……

……

IDENTIFYING AND CONTROLLING VARIABLES

……

……

……

……

……

EXPERIMENTING

……

……

……

……………………………………………………………………………………………………

……………………………………………………………………………………………………

HYPOTHESISING

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

PREDICTING

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

INTERPRETING DATA

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

OBSERVING

………

………

………

………

………

Appendix F: Focus Group Interview for Pre-Service Biology Teachers.

Hello, my name is Adekemi Adewumi and thank you for agreeing to participate in this study. For a quick round of introductions, please tell the group your name, the level of study and the course you are studying at this university (Adekunle Ajasin University, Akungba-Akoko, Ondo State).

The purpose of this study is to explore how you, pre-service teachers, use science process skills (SPS) in understanding biological concepts within the context of plant taxonomy; examine the factors that influence how you use them (SPS) to understand biology, and to know the SPS you developed for understanding plant taxonomy.

Before we start this interview, please note that it is confidential. Your contributions will be anonymized. Furthermore, your name will not be linked to the results of the research. Please note that participation in the discussions is also voluntary. Thus, you have the right not to answer any question that you are not comfortable with, and you may withdraw from this focus group interview at any time. You are encouraged to be as open as possible and respect each other's views/opinions no matter how different their answers may be to yours. The interview will take about 45 minutes.

Do you allow me to record this interview to help me aid my memory and support the notes that I will take?

Matching focus group interview (FGI) questions to CHAT

Component of CHAT	The component in this context	Matching questions/items (FGI schedule)
Subject	Pre-service teachers in relation to the use of science process skills (SPS) to understand biological concepts	1. Do you prefer to learn about plant taxonomy by studying content only or by using SPS? Explain why you prefer your choice.
Tools	Resources (e.g., textbooks, relevant websites, etc.) available to the teachers and the pedagogy using SPS	1. What aspects of the learning about plant taxonomy do you like and how has that hindered or improved your biology literacy or understanding of plant taxonomy? 2. Tell me what you think about studying plant taxonomy using SPS.
Rules	Rules (e.g., curriculum requirements, University rules and regulations, Cogen rule) about the use of SPS to understand biological concepts	1. Do you think your lecturers follow the rules concerning the teaching of plant taxonomy (e.g., curriculum requirements and the university rules concerning SPS, and cogen rules)? 2. How much time do you spend studying biological concepts using SPS?
Community	Activities of pre-service teachers' community	1. Do you use SPS when learning plant taxonomy? 2. Tell me about the reasons behind their use.
Division of labour	Roles undertaken by the pre-service teachers in the use of SPS to understand biological concepts	1. Tell me what you use when using SPS to understand biological concepts better. 2. What do you use that (in 1.) for?
Object	Contextual factors that shape pre-service teachers' views concerning the use of SPS to understand biological concepts.	1. Do you prefer using SPS in learning plant taxonomy? Please give reason(s) for your answer. 2. What difficulties do you have when using SPS to study plant taxonomy?

Appendix G: Science Process Skills Test (SPST)

Answer ALL the questions in the spaces or boxes provided.

1. OBSERVING

Figure 1 below is a model of a dichotomous key of several samples of leaves.

Observe the leaves carefully.

Use evidence in Fig. 1 to name the trees from which the eight leaves, that is, A, B, C, D, E, F, G and H have been taken.

………
………
………
………
………
………
………

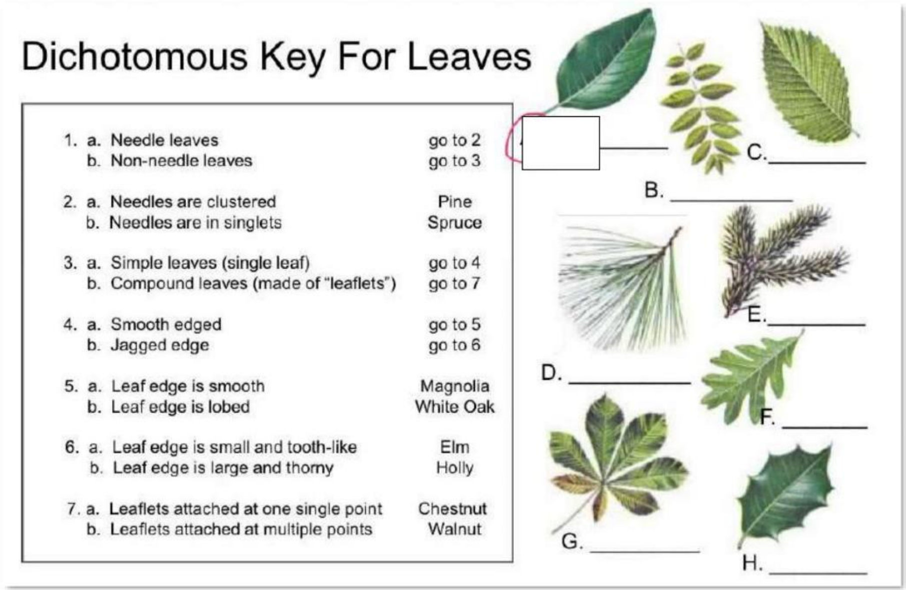


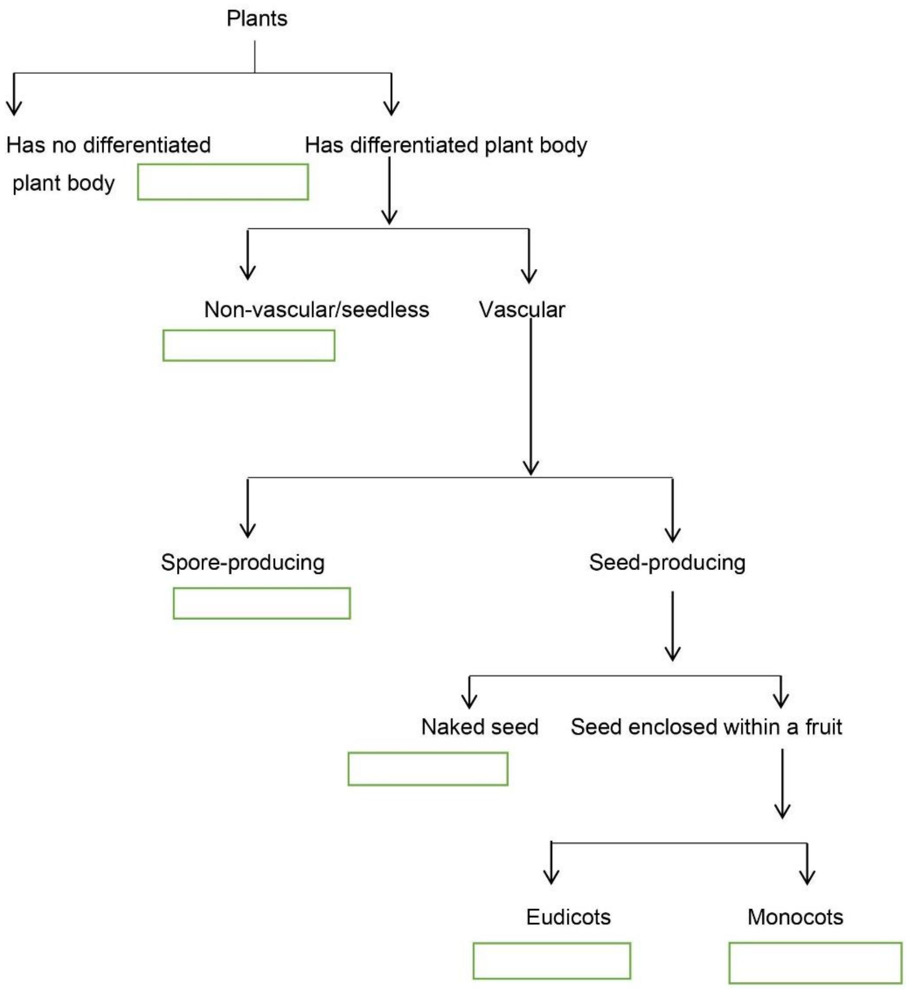
Figure 1. A model of a dichotomous key for leaves

2. CLASSIFYING

The diagram below shows a branched key for several plants.

Classify the items provided below by placing each one of them in the appropriate box of the branched key.

Items: Algae, Moss, Fern, Conifer, Legumes and Orchids



3. **HYPOTHESISING**

A Biology teacher wanted to show her class the relationship between light intensity and the rate of plant growth. She carried out an investigation and got the following results.

Light intensity (Candela)	**Plant growth rate (cm)**
250	2
800	5
1000	9
1200	11
1800	12
2000	15
2400	13
2800	10
3100	5

Using the table above, state the hypothesis for the investigation carried out

………

………

………

………

4. **IDENTIFYING AND CONTROLLING VARIABLES**

You are evaluating the effect of different types of fertilizers on plant growth. You plant 12 tomato plants and divide them into three groups, where each group contains four plants. To the first group, you do not add fertilizer and the plants are watered with plain water. The second and third groups are watered with two different brands of fertilizer. After three weeks, you measure the growth of each plant in centimetres and calculate the average growth for each type of fertilizer.

Treatment	Plant Number				
	1	**2**	**3**	4	**Average**
No Treatment	10	12	8	9	9.75
Brand A	15	16	14	12	14.25
Brand B	22	25	21	27	23.75

- **What are the independent and dependent variables in this evaluative activity?**

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

- **Briefly state how you would have made the results more credible**

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

5. OPERATIONAL DEFINITION

A school gardener cuts grass from seven different football fields. Each week, he cuts a different field. The grass is usually taller in some fields than in others. He makes some guesses about why the height of the grass is different.

What is the testable explanation for the difference in the height of grass?

………

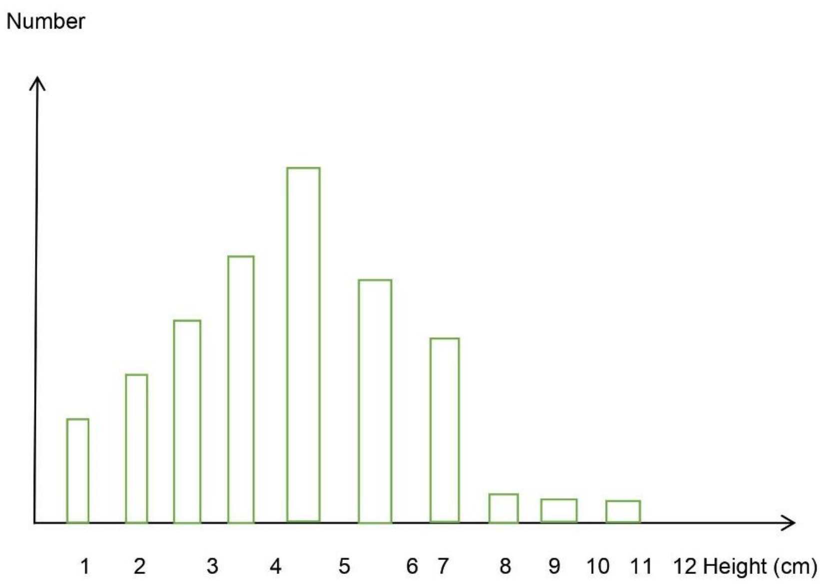
………

………

………

6. INTERPRETING DATA

A group of students measured the height of balsam plants in the school science garden. The results are shown in the graph below.



- **What is the height of the largest number of plants in the garden?**

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

- **What is the maximum height of the plants found in the garden?**

……………………………………………………………………………………………………

……………………………………………………………………………………………………

7. **EXPERIMENTING**

A lady grows roses as a hobby. She has six red rose plants and six white rose plants. A friend told her that rose plants produce more flowers when they receive morning sunlight. She reasoned that when rose plants receive morning sunlight instead of afternoon sunlight, they produce more flowers.

- **What can she do to test her friend's idea?**

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

8. **PREDICTING**

Engelmann, the German botanist, performed experiments to measure the effect of different colours of light on photosynthesis using prism, algae and bacteria. The prism was used to expose algae to the visible light spectrum.

He observed that oxygen-dependent bacteria accumulated on the algae more in the areas of the red and blue light, which indicates that these wavelengths of light are most suitable for photosynthesis (see the diagram below).

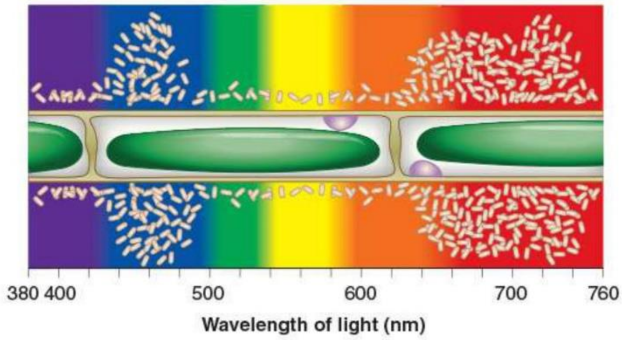


Diagram showing the results of Engelmann's experiment

Predict what would have happened if he experimented without the prism.

....

....

....

....

9. **MEASURING**

Four students were each given their own plant. Each child was told to measure the height of the plant four times during a single class period to practise their measuring skills. The results are shown in the table below.

Students	Measurements			
	1	2	3	4
Rusty's plant	3cm	6cm	10cm	8cm
Mike's plant	4cm	5cm	5cm	4cm
Karen's plant	2cm	10cm	4cm	8cm
Carol's plant	8cm	3cm	2cm	1cm

Which students measured most plants carefully and precisely? Give reasons.

………

………

………

………

Appendix H: Biological Literacy Instrument

Answer ALL the questions in the spaces provided.

Note. For Questions 2 and 3, select the correct answer from those provided in the bracket.

1. Define plant taxonomy.

Plant taxonomy can be defined as the branch of botany which deals with characterisation, identification, classification and nomenclature of plants based on their similarities and differences

OR

Plant taxonomy is the science of classifying and naming plants.

2. During bioremediation, micro-organisms (such as bacteria) are used to (Clone genes from multicellular organisms, Introduce correct genes into individuals that have genetic diseases, Decrease pollutants in the environment, Produce useful products such as insulin for diabetics)

………… Decrease pollutants in the environment.

3. The Common Cold is caused by viruses which enter the body through the nose and throat. If you treat a cold with an antibiotic, what would happen? (The cold would get better more quickly than if you just took ordinary paracetamol, The antibiotic would do nothing to the virus itself, but could prevent possible effects such as pneumonia or an ear infection, It would not hurt the body, even if it had no effect on the virus, It would be dangerous to the body as antibiotics do nothing to viruses but increase the possibility of harmful bacteria becoming resistant to the antibiotic)

   The antibiotic would do nothing to the virus itself but could prevent possible effects such as pneumonia or an ear infection.

Figure 1 shows a branched key depicting the classification of plants into seedless and seed-bearing plants.

Refer to the figure to construct the associated dichotomous key below. The first part of the key has been done for you.

1a. Plants that make seeds………...**go to 2**

1b. Plants that do not make seeds………………………………………………..**go to 3**

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

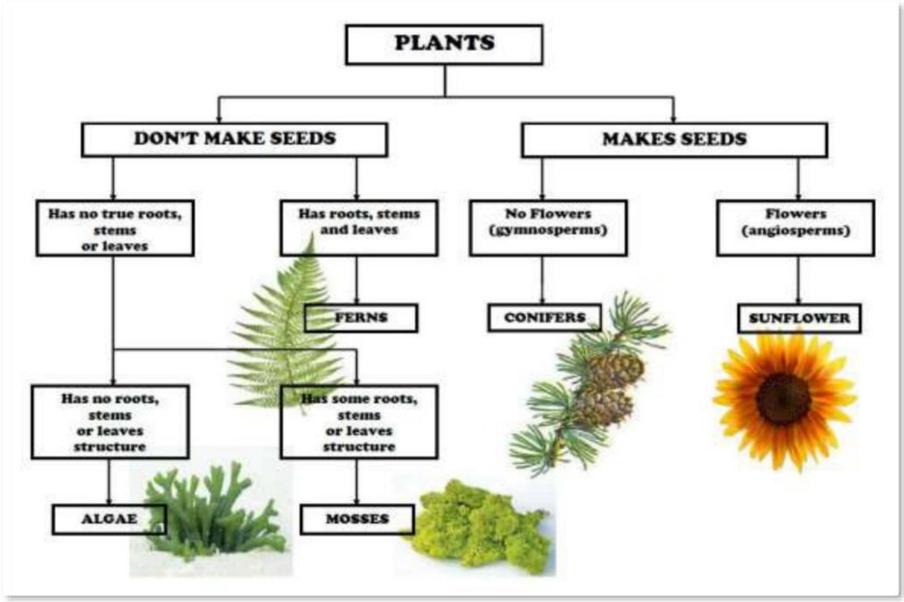


Figure 1. A branched key for algae, mosses, ferns, conifers and sunflower

Appendix I: Language Editing Certificate

Registered with the South African Translators' Institute (SATI)

Reference number 1000686

04 February 2024

Pre-service teachers' use of science process skills in understanding biological concepts based on plant taxonomy in a Nigerian University

This confirms that I edited substantively the above document, including a Reference list. The document was returned to the author with various tracked changes to correct errors and clarify meaning. It was the author's responsibility to attend to these changes.

Yours faithfully

[redacted]

Dr. K. Zano

Ph.D. in English

kufazano@gmail.com/kufazano@yahoo.com

+27631434276