Doctoral Dissertation

An Investigation of Primary School Teachers' Conceptual and Operational Understanding of Science Process Skills in Zambia

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SUMMARY

Introduction:

As a developing nation, Zambia has been improving the quality of science education through broader educational goals. Through the ministry of education, the country focuses on equipping "learners with fundamental scientific knowledge, process skills and values that are essential to contribute to the attainment of vision 2030" (Ngandu & Kaulu, 2020, p. 204). The current curriculum emphasizes the learners' acquisition of Science Process Skills (Banda, 2013). However, learners in Zambia display "weaknesses in questions involving science process skills in science subjects' practical activities" (ECZ, 2016; 2017 in Ngandu & Kaulu, 2020, p.204). The problem has been credited "to weaknesses such as lack of process skills experimentation ability and weakness in expressing ideas when writing answers to examination questions" (Ogunleye, 2012, p.4). The learners' inadequate skills acquisition and development could be due to their teachers' insufficient conceptual and operational understanding of the scientific skills. One study reveals that Zambian primary school teachers displayed an inadequate understanding of the assessment of Basic Science Process Skills (BSPS); this is a concern that calls for an investigation (Mushani, 2021c).

Main Purpose

The study intended to examine the trend of Zambian primary school teachers' conceptual and operational understanding of Science Process Skills (SPS) and study the patterns of Zambian primary school teachers' conceptual and operational understanding of Science Process Skills (SPS) concerning five selected variables, with regards to previous research studies.

Method:

The method section of this study involved two stages: (A) Systematic literature review by qualitative research design for research questions one (1) and two (2). Research question one (1) focused on integrated analysis of previous research studies on the trends in research on SPS from developed and developing countries focusing from three perspectives: (i) Science Curriculum, (ii) Teacher education and (iii) 21st Century Learning. Likewise, research question two (2) used a systematic literature review through an integrative review of the literature using four (4) key search terms, Science Process Skills, Understanding, 21st Century Learning, and Africa. (B) Descriptive and Correlation method by quantitative research design was for research question three (3). This stage was centred on the positivism paradigm using Association Quantitative research method design. This design "relies on the hypothetical deductive method to verify a priori hypotheses that are often stated quantitatively where functional relationships can be derived between casual and explanatory factors (independent variables) and outcomes (dependent variables)" (Park et al., 2020, p.690). The stage was sub conducted into two, i.e., (i) primary school teachers' conceptual understanding of science process skills and (ii) primary school teachers' operational understanding of these skills.

The researcher obtained study data from existing literature on science process skills education and two surveys administered two times. The survey instruments are composed of the Teachers' Conceptual Understanding of Science Process Skills Test (TCUSPST) and Teachers' Operational Understanding of Science Process Skills Test (TOUSPST). The items used in both tests were adapted from the 5th Edition of Learning and Assessing Science Process Skills Book (Rezba Richard J, 2007) and (Molefe, 2016). Part A covered the respondents' demographic information, including gender, teaching experience, teaching qualification, and teaching grade level. Part B comprised the standardized questions regarding the conceptual and operational understanding of science process skills as the dependent variables analyzed statistically across five independent variables: gender, teaching experience, teaching qualification, teaching grade level and teachers’ facilitation of SPS.

Results:

Findings on research question one showed that “the representation rate of SPS is inconsistent with each other” Duruk et al., 2017, p.124) in science curriculum documents and the curriculum implementation at all science education levels. SPS development is needed by considering more vital treatment programs for pre-service and in-service teachers. Teacher educators play an indispensable role instructionally in pre-service education. Their training influences the development of students' SPS. Not many studies on SPS education concerning 21st Century Learning have been done in advanced and emerging countries. Teachers' understanding of SPS facilitates students to study science out of SPS usage in the science education practice. Findings on research question two include the crucial necessity to grow the workforce with systematic understanding and competencies essential for trade advancement in Africa. Despite being in the 21st Century, the African continent records poor socio-economic conditions due to nominal economic growth—demand for quality science education for Africa.

The findings for research question three are in two segments: results under teachers’ conceptual understanding of SPS and those under the operational understanding of SPS. Respondents' conceptual understanding of SPS showed no significant difference across gender, but a substantial difference across teaching qualification variable was noted. Despite reaching statistical significance, the actual mean difference between the teaching qualification categories for respondents’ conceptual understanding of SPS was relatively small (Ƞ2= 0.2). As for the teaching grade-level variable, a nonoccurrence pattern is realized in respondents' conceptual understanding of SPS. Lastly, respondents' conceptual understanding across the teacher SPS facilitation level variable reflects a series of records that repeats plainly.

Findings under respondents' operational understanding of SPS across gender was substantial, with a medium effect size found (d=0.6). There is no significant difference ($p>0.05$) in teachers' operational understanding of SPS across teaching experience and qualification variables. As for the teaching grade-level variable, a nonoccurrence pattern is realized in teachers' operational understanding of SPS. Lastly, participants' operational understanding across the teacher SPS facilitation level variable reflects previous research findings that repeat identifiably.

Conclusion:

This study's findings concerning respondents' conceptual understanding and their operational understanding of SPS are general directions. This study displays various patterns for respondents' conceptual and operational understanding of SPS across the five independent variables. There was a non-repeated occurrence across the gender variable, while their conceptual understanding of these skills showed a repeated occurrence. A non-repeated occurrence was observed from the teaching experience variable, while the teaching qualification variable displayed a repeated occurrence for both respondents' conceptual and operational understanding of SPS. As for the teaching grade-level variable, the unreported occurrence was shown for the respondents' conceptual and operational understanding of SPS. Finally, the respondents' perspective and perception of their facilitation of the SPS variable bears a repeated occurrence.

Respondents' operational understanding of SPS is relatively above average; thus, it can be deemed as reasonable to confirm the findings from previous studies such as Hafizan et al. (2012). Zambian primary school teachers involved (regardless of their gender, teaching experience, teaching qualification, teaching grade level) have a low conceptual understanding of SPS. Previous studies recounted that educators with an inadequate conceptual understanding of SPS could not apply efficient instruction and associate education approaches in their teaching space (Mushani, 2021b).

The necessity for teachers' understanding of SPS's peak and the didactic importance of these abilities should be overvalued. Outstanding teachers' interpretation of SPS along with its application in science education can influence prospective fiscal personnel and investigators in Zambia and Africa in general, where the usage of scientific information is yet modest. The teacher training system in Zambia should have a clear content outline concerning SPS education to enhance the effective acquisition and development of these skills by in-service and pre-service teachers in the various teacher training institutions. Curriculum developers and implementors should consider quality and efficient SPS facilitation at each primary school grade level. Finally, a strong linkage among the curriculum developers, curriculum implementers, Examination bodies, and teacher training institutions will help promote quality SPS education through teaching and learning activities to achieve the country's educational goals and Vision.

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DEDICATION

I commit this dissertation to the Almighty God for the Sovereignty and to the Redeemer of my soul.

To Donald Ngoma,

my amazing husband,

whose sacrificial care for our daughters made it possible for me to complete my work.

And to Angelica Lusungu Ngoma, Gianna Chimwemwe Ngoma, who are indeed a treasure from the Lord, Our Creator.

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LIST OF ACRONYMS

CDC	**Curriculum Development Center**
OECD	**Organization for Economic Co-operation and Development**
ECZ	**Examination Council of Zambia**
EOF	**Educating Our Future**
ER	**Education Reforms**
FOL	**Focus On Learning**
GRZ	**Government Republic of Zambia**
HDI	**Human Development Index**
JICA	**Japan International Cooperation Agency**
MoGE	**Ministry of General Education**
MOE	**Ministry of Education**
PISA	**Programme for International Scientific Assessment**
UNDP	**United Nations Development Programme**
UNESCO	**United Nations Educational, Scientific and Cultural Organization**

CHAPTER 1: INTRODUCTION

Chapter Overview:

In this chapter, the study's background focuses on what Science Process Skills are and teachers' understanding of the very skills in science education. Then the research focus covers the purpose and questions followed by the study's originality and the definition of terms. An explanation of the problem statement and significance follows. The chapter ends with an elaboration of the scope and limitations of the study.

1.1 Background of the Study

Science teaching and learning has since become a significant focus in many countries. Of late, intensified consideration is being granted to demonstrate science's responsibility in our daily lives to humanity. Teachers hope their pupils possess a bright outlook towards learning then value impacts from science studying. Teaching and learning science involve the subject matter and operation elements of science. The subject matter consists of science concepts and processes consisting of essential skills students need to gain (Inan, 2010, 2011; Inan, Inan, & Aydemir, 2014). Rillero (1998, in Chabalengula et al., 2012) "points out that both science content and science process skills are mutually valuable and complementary" (p.168). Undervaluing operation above the content is unacceptable; both are equally important. Humans benefit from science process skills while solving problems through research in this world we live. To unravel these difficulties, humans ought to attain appropriate science process skills. Teachers should recognize (conceptually and operationally) the science process skills for learners to achieve the required capability (Mutisya, Rotich & Rotich, 2013). Learners need to develop scientific literacy "to think like scientists and understand how scientific theories are constructed and tested" (Arons, 1983 in Zurida & Ismail, 2001, p.68).

Science Process Skills in Science Education

Education programmes aim to attain a core ability: science process skills (SPS). According to Harlen (1999), science process skills are one of the primary goals of science education. "These skills are utilized not only by scientists but also by everyone to become scientifically literate" (Gultepe, 2016, p.780). The process skills should be featured in the science curriculum and every bit of science-associated programs.

There are several definitions of science process skills presented by many authors, as shown in table 1. ensuing.

Table 1. Selected Previous Study Definitions for Science Process Skill Term

No.	Author/Year	Title of Article/Book/Paper	Description/Definition of Science Process Skills
1.	Bredderman (1983)	Effects of activity-based elementary science on student outcomes: A quantitative synthesis	Cognitive skills are used to understand and develop the information.
2.	Ostlund (1992)	Science process skills: assessing hands-on student performance	SPS are the building blocks of critical thinking and inquiry in science.
3.	Gagne et al. (1993)	The cognitive psychology of school learning	Science process skills are problem-solving skills in which a problem is exemplified; a systematic process is performed to solve the problem.
4.	AAAS (1993)	Benchmarks for Scientific Literacy	Habits of mind
5.	NAS (1994)	National Science Education Standards	Scientific inquiry abilities
6.	Gott & Duggan (1994)	Investigative Work in the Science Curriculum	Procedural skills.
7.	Nwosu & Okeke (1995)	The effect of teacher sensitization of students' acquisition of science process skills	Mental and physical abilities and competencies "serve as tools for the practical study of science and technology and problem-solving,

			individual and societal development" (Siachibila, 2018, p. 18).
8.	Aktam & Ergin (2008)	The effect of scientific process skills education on students' scientific creativity, science attitudes and academic achievements	Transferable skills that apply to many sciences and reflect scientists' behaviours.
9.	KARSLI & ŞAHİN (2009)	Developing worksheet based on science process skills:	Science process skills are (SPS) "defined as the adaptation of the skills used by scientists for composing knowledge, thinking of problems and making conclusions" (KARSLI & ŞAHİN, 2009, p. 2).
10.	Lind (1998)	Science process skills: Preparing for the future	The science process skills (SPS) are the "thinking skills we use to create knowledge, reflect on problems, and formulate results" (Lind, 1998 in McComas, 2014, p. 205).
11.	Harlen (1999)	Purposes and Procedures for Assessing Science Process Skills	a. Mental and physical skills. b. "General descriptions of logical and rational thinking, used in many areas of human endeavour" (Harlen, 1999, p. 130).
12.	Özgelen (2012)	Students' Science Process Skills within a Cognitive Domain Framework.	"Science process skills (SPS) are the thinking skills scientists use to construct knowledge to solve problems and formulate results" (Ozgelen, 2012, p.284).
13.	Yumuşak (2016)	Science Process Skills in Science Curricula Applied in Turkey	Means and methods to reach scientific information allow the pupils to think scientifically.

After a profound analysis and evaluation of several definitions and descriptions from previous studies, this dissertation defines SPS as special skills and abilities needed and used in knowledge discovery and creation to understand scientific information and solve problems.

The learning outcomes in science are generated using science process skills by the learner. "Competency in SPS should be viewed as a means that will help students to acquire knowledge and to understand how the knowledge is obtained" (Bati et al., 2010, in Shahali et al., 2017, p.2). Science process skills remain vital to create logical evidence, execute analytical investigation, and resolve complications. These skills enable learners to attain and use knowledge, and they help develop favourable scientific attitudes and character in learners. When learners use science process skills, their curiosity, imagination, and intuition during the learning process improve. The science process skills increase academic achievement in science learning (Aktamis & Ergin, 2008). These process skills aid learners in understanding observable facts or/and events, answering questions, develop a system of ideas or hypotheses, and finding facts or evidence during science lessons and in their life experiences. When classifications of science process skills are studied, there are two primary skills: basic and integrated. There are six (6) Basic Science Process Skills (BSPS): "Observing", "Communicating", "Classifying", "Measuring", "Inferring", "Predicting". The Integrated Science Process Skills (ISPS) are six: "Identifying and Controlling variables", "Defining operationally", "Formulating hypotheses", "Interpreting data", "Experimenting", "Formulating models" (Padilla,1990, p.2-3).

Teachers' Understanding of SPS in Science Education

Many studies have emphasized teachers' understanding of the science process skills (Mushani, 2021). Despite various studies that institute the importance of science process skills for teachers, there is an indication "that elementary teachers lack science content knowledge and inquiry pedagogical skills to teach science teachers effectively"

(Miles, 2010, p. 3). According to Darling-Hammond et al. (2017), "there is hardly any intervention to improve student learning that does not rely on teachers for proper implementation". Teachers who can connect concepts combined with processes around subjects appear towards getting pupils who discover other knowledge and good quality learning (Novak & Gowin, 1984, Hipkins et al., 2002). The teachers' understanding of SPS greatly influences science teaching and learning, which eventually impacts the quality of science education provision (Mushani, 2021a).

As a developing nation, Zambia has been making efforts to improve the quality of science education by putting it at the centre of broader educational goals. It focuses on equipping "learners with fundamental scientific knowledge, process skills and values that are essential to contribute to the attainment of Vision 2030" (Ngandu & Kaulu, 2020, p. 204) – prosperous middle-income nation – (Ministry of General Education [MoGE], 2013). Therefore, it can be contended that the teachers should be more knowledgeable and better understand both the contents and the processes of science (Mushani,2021a). Thus, the curriculum was revised, and some aspects changed to accomplish the Vision. These changes include changing the science 5124 curriculum from content to the outcome-based curriculum (MoGE, 2013)[1]. Additionally, the revised curriculum emphasizes the acquisition of SPS by the learners (MoGE, 2013).

1.2 Problem Statement

The research studies revealed that novice teachers could not interpret science process skills (e.g., Emereole, 2009; Mbewe, Chabalengula & Mumba, 2010). However, few studies

[1] Science 5124 curriculum refers to the revised science curriculum currently in use at high school level whose implementation focuses in students' acquisition and development of scientific knowledge and skills.

discuss the conceptual and operational understanding of science process skills gained by practising science teachers, especially at the primary school level.

Literature has shown that learners in Zambia display weaknesses in questions involving science process skills in science subjects' practical activities (ECZ, 2016; 2017 in Ngandu & Kaulu, 2020, p.204). The problem has been credited "to weaknesses such as lack of process skills experimentation ability and weakness in expressing ideas when writing answers to examination questions" (Ogunleye, 2012, p.4; Ngandu & Kaulu, 2020). The low performance recorded under practical science subjects might be associated with learners' poor or inadequate skills acquisition and development caused by their teachers lacking or possessing an insufficient conceptual and operational understanding of the scientific skills. Another study result states that Zambian primary school teachers displayed an inadequate understanding of the assessment of Basic Science Process Skills (BSPS); this is a concern that calls for an investigation (Mushani, 2021c). No study has extensively investigated the teachers' conceptual and operational understanding of these process skills in Zambia. Therefore, this study focuses on:

1. Examining the trends of Zambian primary school teachers' conceptual and operational understanding of Science Process Skills.
2. Analyzing the patterns of Zambian primary school teachers' conceptual and operational understanding of Science Process Skills across five selected variables.

1.3 Significance: Responding to the Research Problem

This research can contribute to science teaching and learning at all education levels. It has two considerable significances, i.e., Practical and theoretical significance.

1. ***Theoretical Significance*:**

This research shows that despite this being the 21st Century, teachers have an insufficient conceptual and operational understanding of Science Process Skills. A notable disparity in Science Process Skills education between developed and developing nations.

2. ***Practical Significance:***

a. *For teachers:* The results of this study can be used as a reference for teacher self-evaluation to improve their ability in understanding more about Science Process Skills in teaching and learning.

b. *For teacher educators*: The results of this study can help the teacher educator accord SPS education a critical consideration during teacher preparations/training.

c. *For Curriculum and Examination Bodies*: The results of this study can help the education curriculum developers and assessment departments ensure the unbiased incorporation of SPS education in all education documents.

d. *For other researchers*: To give additional information for other researchers who want to conduct further research on the related field.

1.4 Research Focus: Purpose and Questions

1.4.1 Main Research Purpose

To examine the trends and patterns of Zambian primary school teachers' conceptual and operational understanding of Science Process Skills (SPS) concerning five selected variables.

1.4.2 Research Questions

Three research questions guided the investigation to address the critical research purpose.

1) What is the trend of SPS education in developed and developing countries?
2) Why is teachers' understanding of SPS essential in science education for Africa?
3) Research question three has two sub-questions i.e.

A. What is the trend of Zambian primary school teachers' conceptual and operational understanding of SPS?

B. What are the patterns of Zambian primary school teachers' conceptual and operational understanding of SPS across five Independent Variables (Gender, teaching experience, teaching qualification, teaching grade level and teacher facilitation level of SPS?

1.5 Originality of the Study

The study aimed and has been made to fill the literature gap on teachers' understanding of science process skills at the foundation level of education. To the best of the researcher's knowledge, very little has been done to examine teachers' conceptual and operational understanding of science process skills at the primary school level in Zambia. This study thus aims at introducing a novel perspective for considering the significance of teachers' understanding of science process skills with the ultimate goal of promoting quality and effective teacher facilitation and learner acquisition of these skills at all education levels in Zambia.

1.6 Definition of Terms

This section offers explanations based on the theoretical and practical definitions of five key terms used in this study and given below regarding the focus of this research study.

1) Science Process Skills: According to Padilla (1990 in Siachibila, 2018), SPS are "A set of all-embracing, interchangeable abilities suitable to many science disciplines and reflective of a scientist's behaviour" (p. 18).
2) Conceptual Understanding: The breadth and depth of knowledge about concepts that enables one to possess the ability to construct and explain interactions about ideas (Alao and Guthrie, 1999).
3) Operational Understanding: Refers to knowing what to do, when and how much to do, and what indicators to consider when making strategic decisions (Richmond and Gannon, 1996 in Oliva and Bean, 2008).
4) Trend: Refers to the general tendency of a series of data points to move in a particular direction (Oxford Dictionary).
5) Pattern: Refers to a repeated occurrence or sequence (.https://www.vocabulary.com/dictionary/pattern).

1.7 Scope and Limitations of the Study

The study explores the trends and patterns in the primary school teachers' conceptual and operational understanding of SPS. The study has some limitations within which the findings need to be construed carefully. Some limitations of this study should be mentioned; First, due to the Covid 19 pandemic, only a limited number of respondents were available to participate in the study because of disruptions in the running of regular school programmes. Second, the study was done out of a few selected schools within Lusaka and the Central Provinces of Zambia because of travel restrictions. Thirdly, few SPS test instruments on teacher understanding of SPS are available. Thus, data collection instruments used in this study were adapted/modified to be applicable in the curriculum context of the said country.

CHAPTER 2: LITERATURE REVIEW

Chapter Overview:

In the previous chapter, the scope of the study is described by focusing on SPS and teacher understanding of these skills in science education. This chapter elaborates on the history of SPS, why teachers' understanding of the skills is cardinal in the science education context and the need for SPS education in Zambia. A brief background description of Science Process Skills Education in Zambia follows up. This chapter concludes with a summarized table display for selected previous research studies on SPS education regarding the five independent variables.

2.1 History of Science Process Skills

Science Process Skills is founded on Gagne Theory of Learning (AAAS, 1970: Gagne, 1970). As Lawson (1974), stated that to some extent entreating the usual point of view that realize relationships preside the whole information, Gagne believed pupils find an arranged, compelling sequences of abilities, i.e., the extra uncomplicated, particular additional capability is understood prior to the subsequent, further complicated, and ordinary skill. Fundamentally Gagne claims that learning is a progressive impact of unfairness, simplification, and relocation. Learning is a continuous activity as it is. "Research on the learning process focuses on the issue of how learning occurs and how individuals learn" (Duruk et al., 2017, p. 119). Therefore, there is a need for learners to be scientifically literate. "Scientific literacy has been recognized as a major goal of science education in the world" (Turiman et al., 2012, p.112). "In line with developments in technology and the explosion of knowledge in the digital age, the 21st-century skills can be cultivated through scientific literacy and science process skills, especially for science students" (Turiman et al., 2012, p.114)

Traditionally, science is considered the body of facts, laws, formulae, principles, and theories (declarative knowledge – content). Declarative knowledge (content) is knowledge about something, and procedural knowledge (process) is knowledge of how to do something. The other dimension is the processes (procedural knowledge) of science goals which aim to develop learners' ability to master science (skills) to understand science content. The process helps us to understand the world around us. Understanding the world around depends on the development of concepts. Developing ideas depends on the process skills; both are equally important and not mutually exclusive. Thus, the content and process of science are complementary and mutually interdependent. Many research studies concerning process skills stimulated that process skills are continually described as the skills of doing science, and various definitions and components of process skills exist. The most broadly accepted features of process skills are those provided by the American Association for the Advancement of Science (AAAS) that compiled a list of process skills within the curriculum, namely Science—A Process Approach (SAPA). According to Lockard (1975), SAPA was the first curriculum in which science processes were identified and arranged into a learning hierarchy. SAPA divided process skills into two groups: fundamental and integrated processes. SAPA II (1975), a revision of SAPA (1965), lists 13 science process skills which include basic skills : (1) Observing, (2) Measuring, (3) Using Space/Time relationships, (4) Communicating, (5) Classifying, (6) Predicting, (7) Using Numbers, (8) Inferring, and integrated skills: (9) Controlling variables, (10) Interpreting data (11) Defining operationally, (12) Formulating hypotheses, (13) Experimenting.

In addition to SAPA's preliminary list of process skills, these skills listing emanated from other researchers such as Padilla (1990) lists 12 process skills that exclude using space/time relationships and using numbers. Formulating model skill was introduced while controlling variable skill was amplified to identifying and controlling variable and interpreting data skill to analyzing and interpreting data in Padilla's listing of SPS. Ostlund (1992) lists 15 process skills that include estimating, collecting data, and making graph skills. Additionally, investigating skill is listed instead of experimenting skill. The current list of process skills is by Martin et al. (2005). The list includes basic skills of (1) observation, (2) classification, (3) communication, (4) measurement, (5) estimation, (6) prediction, (7) inference, and integrated skills: (1) identifying, (2) controlling variables, (3) graphing, (4) interpreting, (5) modelling, (6) investigating. The SAPA list of process skills is prevalent up to the current date. The description of the process skills varies from one source to another. However, there is a general perception within the definition of each skill (Lumbontobing, 2005).

2.2 Why Teachers' Understanding of SPS in Science Education?

Many empirical studies record the importance of teachers' understanding of SPS in science education. One is the influence on mastery of subject matter during the learning process. Teachers whose understanding of SPS is higher are successful in producing desired or intended results during the science learning process (Mutisya et al., 2013). Another noted influence is enhancing an active learning process: Studies revealed that developed SPS teachers teach these skills more actively in their classrooms (Downing & Gifford, 1996). Improved formative assessment conduct is recorded as a result of SPS influence too.

Research supports "a positive relationship between the cognitive level of questions asked by the teacher and the level of thinking a student experiences in processing an answer" (Levin & Long, 1981 in Downing & Gifford, 1996, p. 66). Efficiency in the learning process: to teach the SPS to students in a well-organized and competent way, teachers should have enough SPS (Miles, 2010 in; Bulent, 2015). Teachers, especially at the pre-service level, must be trained in SPS to teach students to master the subject matter and ways of knowledge acquisition in the science teaching and learning process. (Susanti et al., 2018)). Lastly, the influence pointed out is on the teachers' ability to develop students' SPS during learning. "Science teachers who have a good understanding of SPS will tend to be more capable in developing student SPS than teachers who have little knowledge about SPS" (Permanasari et al., 2013). Additionally, teachers ought to be aware of SPS to enable their students to build up these skills at a preferred level, as asserted by Mutisya et al. (2013).

Teachers' understanding of SPS significantly impacts the science learning process. When teachers' understanding of SPS is high, they are empowered to promote well-organized, dynamic, and operative science learning processes. In addition, teachers' understanding of SPS leads to improving student SPS ability. Teachers must have a high understanding of SPS (conceptual and operational) to facilitate quality student acquisition and development of these skills during the science learning process. Teachers' understanding of SPS helps empower pupils to do science out of SPS usage in the science learning practice. Students taught by teachers' whose understanding of SPS is inadequate to adhere to guidelines and obtain excellent scores devoid of gaining a theoretical and operational insight of the skills employed.

According to Emereole (2009), “Creativity and originality, which are hallmarks of scientific investigations, would be difficult to develop from poor conceptual and operational backgrounds (p.1052). Through the application of SPS creation of scientific knowledge by students, they can transfer and apply it later in life. Therefore, teachers’ understanding of SPS influences these skills during the science learning process and has long-term effects on student science learning.

Table 2. The Importance of Teacher Understanding of SPS on the science learning process

Author/Year	**Important Aspect of Science Process Skill**					
	Facilitates Effective Learning	**Promotes Efficient Learning**	**Enhances Active Learning**	**Advances Assessment**	**Improve Mastery of Concepts**	**Aid Quality SPS Education**
Mutisya et al. (2013)	✓					✓
Downing & Gifford (1996)			✓			
Wilen (1987)				✓		
Miles (2010)		✓				
Susantia, Anwar & Ermayanti (2018)					✓	
Hamidah et al. (2013)						✓

2.3 Zambia Education System

2.3.1 Primary and Secondary School System in Zambia

The Ministry of General Education (MoGE) is Zambia's leading formal education provider. Primary education is part of basic education which is split into three levels: lower basic (grades 1-4), middle basic (grades 5-7) and upper basic (Junior Level – grades 8-9) (MOE, 2009 in Masaiti & Chita, 2015). Primary and secondary schooling structure is highly related to the British standard, with 7 years of primary education and five years of post-primary or secondary education (Thomas et al., 2020). Initially, Zambia's prescribed education classification structure owned seven years of initial schooling (four years of junior and three years of high initial education), five years of intermediate education and four years of undergraduate higher education (MOE, 1997). Then later, this structure had a transition from 7-5-4+ to 9-3-4+ covering grades one to nine of fundamental schooling (grade 1-9), grades 10 to twelve of high school (grades 10-12), and a four-year course of undergraduate education. Reasonable public assessments define the conversion from primary to secondary learning stages at the 7th, 9th and 12th levels.

Since 2019 the Ministry of General Education launched specialization at the primary school level. Subjects taught at Primary School include English Language, Mathematics, Social Studies, Integrated Science, Home Economics, Technology Studies, Expressive Arts, and Zambian Language. The following areas are Grade 1-4 (Lower Primary School Level)- (i) Literacy only, Science and CTS, Science and Maths. For Grades 5-7 (Upper Primary School Level), subjects specialization areas include English and Zambian Language, Science and Creative and Technology Studies (CTS), Science and Maths. Also, Home Economics (H.E) and Technology Studies (teachers who are handling H.E and Technology Studies should be different), Social Studies and Expressive Arts.

2.3.2 Teacher Education System in Zambia

From the Zambian perspective, teacher education implies the rules and processes devised to prepare potential school teachers with the expertise, viewpoints, behaviours, and competencies to execute duties efficiently (Chishimba (1996). Teacher education curriculum consists of Early childhood education primary and secondary school teacher education. All learning institutions offer two kinds of curricula in Zambia: Pre-certified teachers and certified Teacher Education curricula. Particular institutes of education specify the length of the pre-certified undergraduate curriculums however is non to a lesser extent than four years for the bachelor course. In comparison, certificate programs are not to a lesser extent than three years. Updating programs for both uncertified and certified teachers remain accomplished within the duration stated earlier (MoE, 2013).

Up until now, self-governing Zambia has had three essential policy documents on education which have had an underlying influence on the theory and practice of teacher education (TE) (Musonda, 1999). The first was the Educational Reform (ER) of 1977. Educational Reform (ER) emphasized education as an instrument for personal and national development. The second policy reform was Focus On Learning (FOL), launched in 1992. Its emphasis was on basic education (nine years of initial schooling). The Jomtien Conference influenced this policy, which advocated universal basic education for all in 2000. The policy established that primary education completion helps alleviate poverty ignorance and advances economic and social development. In this Policy, TE aimed to transform school leavers into experts of the concept matter suitable at the foundation stage, proficient in educating abilities and instilled perception of qualified dedication to teaching learners and the children (Ministry Of Education (MOE), 1992). Zambia changed its political system and ideology. It now embraces liberal democracy. In 1996, the third educational policy, Educating Our Future (EOF), was formulated currently in use at present. It emphasizes those skills and competencies crucial in the modern world's intensely competitive [economic] climate than ER did. As far as teacher education is concerned, the current policy considers the ‘‘essential competencies required in every teacher are mastery of the material to be taught, and skill in communicating that material to pupils’’ (MOE, 1996; p. 108).

The system of teacher preparation comprised four routes:

1. *Certificate-level* teachers for Grades 1—7 who undertake their training in primary teacher training colleges. Trainees undergo a two-year residential training in about 14 traditional subjects in the primary school curriculum.
2. *Diploma-level* subject specialist teachers for Grades 8 and 9 follow a two-year training programme in which students follow education courses and specialize in one, two or three teaching subjects. These are partner institutions, and the University of Zambia (UNZA) regulates the practice, checks the requirements, and does the school accolades for every institution.
3. *Diploma-level* specialist teachers (of Music, Art, Agricultural Science, Industrial Arts) trained in other institutions that are not necessarily Teacher Training Colleges and administered by other Government Ministries rather than the Ministry of Education.

4. *Graduate teachers* for Grades 10—12, trained at the university. A parallel course where undergraduates select didactic basics and practice courses but focus on one or two instruction disciplines.

Initially, school teachers trained in the Zambia Primary Course program obtained a certificate at the end of the two-year program. They were instructed to teach all the subjects at the primary school level. (CDC,2013). Teachers at the primary level can currently train in diploma and degree programs specializing in particular subjects. Some are upgrading from certificate to diploma and degree courses. At the same time, some teachers pursue diploma and degree courses directly without having done certificate programs before.

2.3.3 A Brief Background on Science Process Skills Education in Zambia

The Science Process Skills were notable in the science curriculum during the curriculum review process initiated by the Curriculum Development Centre (CDC), Ministry of General Education (MoGE) in Zambia with the technical support from JICA experts (Curriculum Support (Science Analysis)) in the year 2013. JICA expert implemented the review of topic flow in science syllabi from Grade 1 to Grade 12 in collaboration with CDC by providing technical support. As a result, systematic syllabi that reflected SPS education was produced. The new science syllabi first introduced skills in its "Verb" form based on the idea of "Science Process Skill" then described specific "learning activities and action/ as objects of the verb (JIBUTSU, 2013). This process ignited the revision of the whole education “curriculum from a knowledge-based one, which it had been using since its political independence from the British in 1964, to a competency-based one or outcome-based curriculum” (Mulenga & Kabombwe, 2019, p. 118).

Unfortunately, despite revising the curriculum done eight (8) years ago, learner performance in science and some related subjects is still poor, according to the 2020 statement of the Committee on Education, Science and Technology for the fourth meeting of the duodecimal National Assembly:

"The quality of education in Zambia was said to have improved tremendously over the years, but not so with science, technology, engineering, and mathematics subjects. Educational outcomes of these subjects were generally poor in many schools, compelling think tanks to link the below-par performance of learners to, among other factors, the capacity of teaching science, technology engineering and mathematics. One question that begged an answer was, "were the teachers and tutors well-equipped to teach these subjects?" (pp. 2 of NAZ, 2020).

The Vision 2030 for Zambia focuses on industrialization and diversification to achieve middle-income status (GRZ, 2006). The industrialization and diversification priorities depend on improving the technology, engineering, and mathematics knowledge and the scientific knowledge and skills levels. Producing investigative, innovative, and creative learners and graduates for the country's socio-economic transformation is among the goals of science education in Zambia. However, "Zambia is still one of the five worst performers on human development indicators, along with the Democratic Republic of Congo, Malawi, Mozambique, and Zimbabwe" (World Bank, 2017, p.16). The identified problem is the lack of appropriate education, training, and efficient vocational guidance in line with industrial needs (Mulenga & Kabombwe, 2019). One study stated that ECZ administered theoretical examinations in science 5124, but the practical test was incorporated following the curriculum review (Ngandu & Kaulu, 2020).

The Examination Council of Zambia (ECZ) annual performance reports have revealed that “candidates have been displaying weaknesses in questions involving the use of science process skills in chemistry practical activities” (Ngandu & Kaulu, 2020, p. 604). On the other hand, another study revealed that the number of basic science process skills was significantly higher than the number of integrated science process skills in the Examinations Council of Zambia (ECZ) 5070/3 practical chemistry examinations in 2007-2016 (Siachibila & Banda, 2018). Vision 2030 is a longstanding state expansion blueprint for the nation, and it offers a tactical aim on where the country is anticipated designated by 2030. The exact composition of the Vision is of Zambia turn into A Wealthy Mid-revenue Country. This concept implies the manner of resident the nation aspires. Thus, the need for SPS education becomes paramount.

2.3.4 The Need for Science Process Skills Education in Zambia

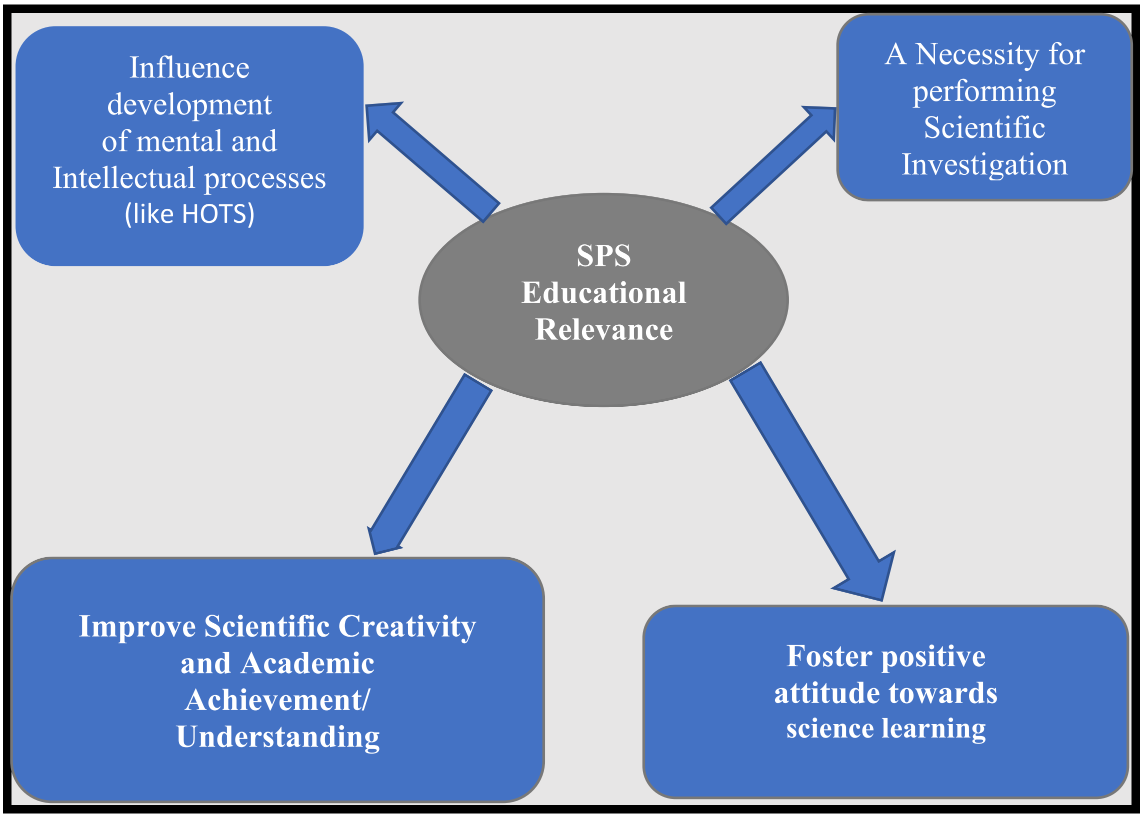
Zambia's Ministry of General Education has set up some goals, which include producing a learner who:

i. “Is analytical, innovative, creative, versatile, employable, entrepreneurial, productive and constructive”;
ii. “Appreciates the relationship between mathematical and scientific thought, action and technology on the one hand and sustenance of the quality of life on the other” (CDC, 2013, p.8).

Previous research studies on the academic relevance of SPS are that these skills are an essential key factor in studying knowledge that impacts one's science education. And literature has affirmed how SPS education is necessary to help attain the set education goals outlined in the Ministry of General Education of Zambia.

Using the SPS, students are abetted in developing competence in searching for knowledge and information using scientific methods, which would be helpful in non–science education sectors and future life pursuits. These skills help students learn how to learn because, in the learning process, SPS serves as the basis of scientific methods and is also an essential aspect in learning about the characteristics of knowledge (Hikmah et al., 2018). In addition to the stated educational importance of SPS, they are also processes of inquiry that form the basis of all the scientific disciplines such as mathematics and logic, biological, physical, and social science (Mushani, 2021). Figure 1 gives a summary display of the educational relevance of SPS.

Figure 1. Educational Relevance of Science Process Skills



2.4 Related Factor

Five variables are deemed for this study to systematically analyze the trends and patterns in Zambian primary school teachers' conceptual and operational understanding of SPS. These include; Gender, teaching experience, teaching qualification, teaching grade level, and teachers SPS facilitation level. The variables were identified based on the tendency of previous research studies on SPS education, as shown in Table 4.

Table 3. Previous Studies on SPS Education Basis for Selecting of 5 Independent Variables

Author/s & Year	Gender	Teaching Experience	Teaching Qualification	Teaching Grade Level	Teachers SPS Facilitation
1. Mutisya et al., (2013)	✓				
2. Shahali et al., (2017)	✓	✓	✓		
3. Berge, Z. L. (1990)	✓				
4. Osman, K. (2012)					✓
5. Erkol, S. & Ugulu, I. (2014)	✓			✓	
6. Permanasari et al., (2013)					✓
7. Al-rabaani, A. (2014)	✓				
8. Kruea-In, et al., (2015)		✓			
9. Ong et al., (2015)	✓			✓	
10. Myers et al., (2004)	✓	✓	✓		

CHAPTER 3: RESEARCH METHODOLOGY

Chapter Overview:

The previous chapters explained 'why' and 'what' the present research is. Thus, the section responds to the 'how' the research occurred to answer the 'what' subject. Chapter three begins with a narrative of the study's complete layout for three stages; the chapter then explains how the study was framed theoretically and conceptually and elaborates on the theories and concepts followed up. Then a discussion on the dimensions and constructs is covered in the conceptual framework with the figure of the study's analytical framework. The chapter concludes with an elaboration of the structure of the dissertation.

3.1 Overall Study Design

Qualitative and quantitative designs guided this study. A qualitative design is employed in the first two research questions, and the quantitative is used in the third and final research question. The research study has a three-stage method under the methodology section. The first involves an integrated analysis of previous research studies on teachers' understanding of SPS in developed and developing countries. The second focuses on analyzing previous research studies on the importance of teachers' understanding of SPS in science education globally, focusing on Africa. The third and final stage method centres on the positivism paradigm. It employed the Associative Quantitative research method design to determine the relationship between two or more variables (Cohen, Manion & Marrison, 2005).

Details on each stage method are presented in three successive chapters covering the three research questions that guided the investigation to address the critical research purpose.

Three Study Frameworks (Theoretical, Conceptual & Analytical Frameworks)

The conceptual framework presents the overall structure of the study, while the theoretical framework explains the relationship investigated within the study; on the other hand, the analytical framework discusses where the conceptual framework leads up.

3.2 Theoretical Framework for the study

This study has adapted the positivism paradigm to identify "explanatory associations or causal relationships that ultimately lead to prediction and control of the phenomena in question" (Park et al., 2020, p. 690). "In this regard, generalizable inferences, replication of findings, and controlled experimentation guide this theory. Positivism depends on the hypothetical inferential procedure to validate previous assumptions regularly asserted quantifiably. Operational connections could be derivative between independent and dependent outcomes. Dependent variable refers to quantities of attention in the research; dissimilar to independent variables, dependent variables can be evaluated, not controlled. Then the Independent variable is the factors that influence the outcomes of the Survey. As pictured in figure 3.1, this framework has three fundamental areas: Science Process Skills, Conceptual Understanding, and Operational Understanding.

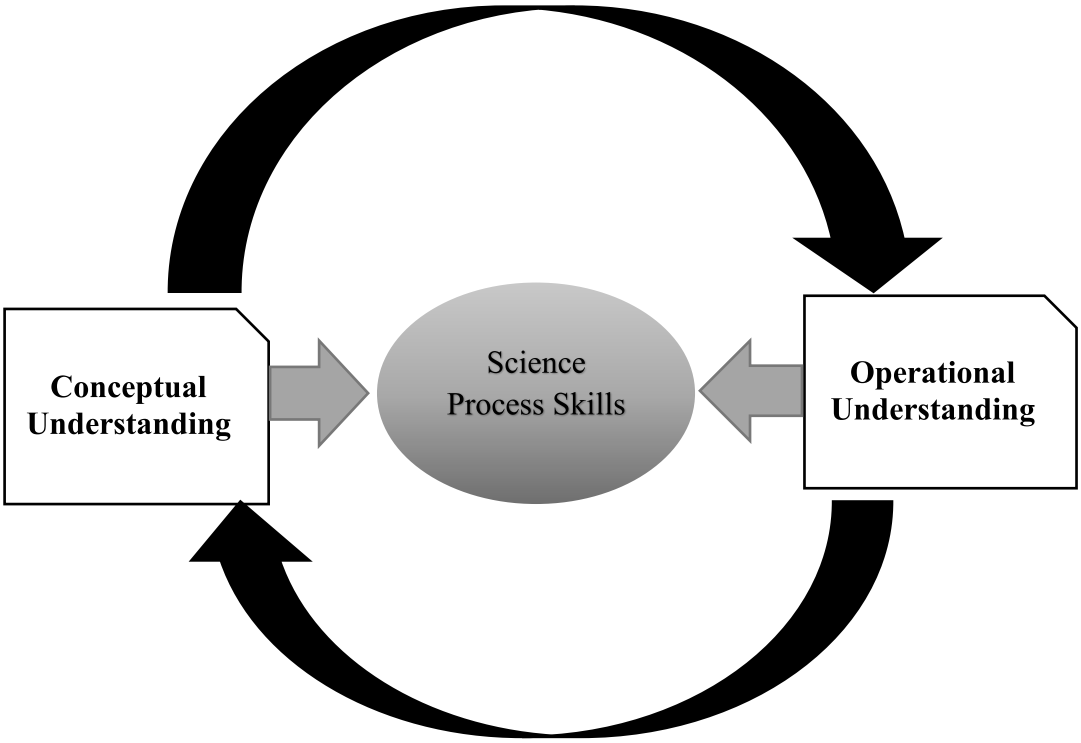
In this study, these essential areas in the theoretical framework will guide to determine the current state of primary school teachers' understanding of science process skills in Zambia.

i. Science Process Skills: this term refers to the unique skills and abilities needed and used in knowledge discovery and creation to understand scientific information and solve problems.

ii. Conceptual Understanding is the breadth and depth of knowledge about concepts that enables one to possess the ability to construct and explain interactions about ideas.

iii. Operational Understanding refers to realizing what to do, when and how much to do, and what indicators to consider when making strategic decisions.

Figure 2. Diagrammatic Representation on the Theoretical Framework of the study

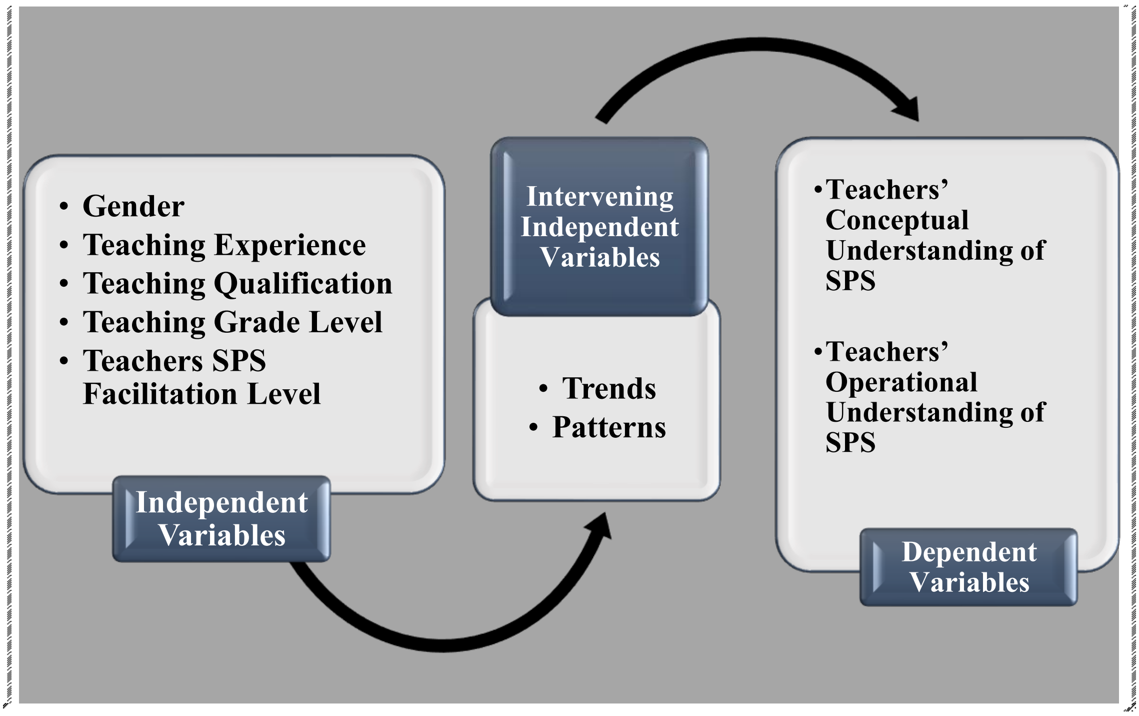


3.3 Conceptual Framework of the Study

This section illustrates what the researcher expects to find in the research study. It provides a clear guide on the directions to the research through a conceptual framework. According to Ravitch and Riggan (2017), a conceptual framework guides and stabilizes research. They function as an amalgamating environment that assists investigators purposefully taking the entire facets of research jointly by clarifying their connections, disjunctures, overlaps, tensions, and the contexts shaping the study of the phenomena in the setting. The researcher uses the conceptual framework design to help identify and clarify what to know about this study and show the connection among the central aspects of the study on how they influence this research. The significant variables are expressed too.

Figure 3.2 ensuing displays an illustration of an expected relationship between the variables in this study. Conceptual and operational understanding of SPS featured as dependent variables while five constructs are selected purposively as independent variables of the study. In addition to the Independent Variables (ID) and the Dependent Variable (DV) are two Intervening Independent Variables (IID), Trends and Patterns. An intervening variable, also known as a mediator variable, is a hypothetical variable used to explain links between other variables (Glen, 2019). The use of mediating variables in this study makes it distinctive compared to previous research studies in this field of focus.

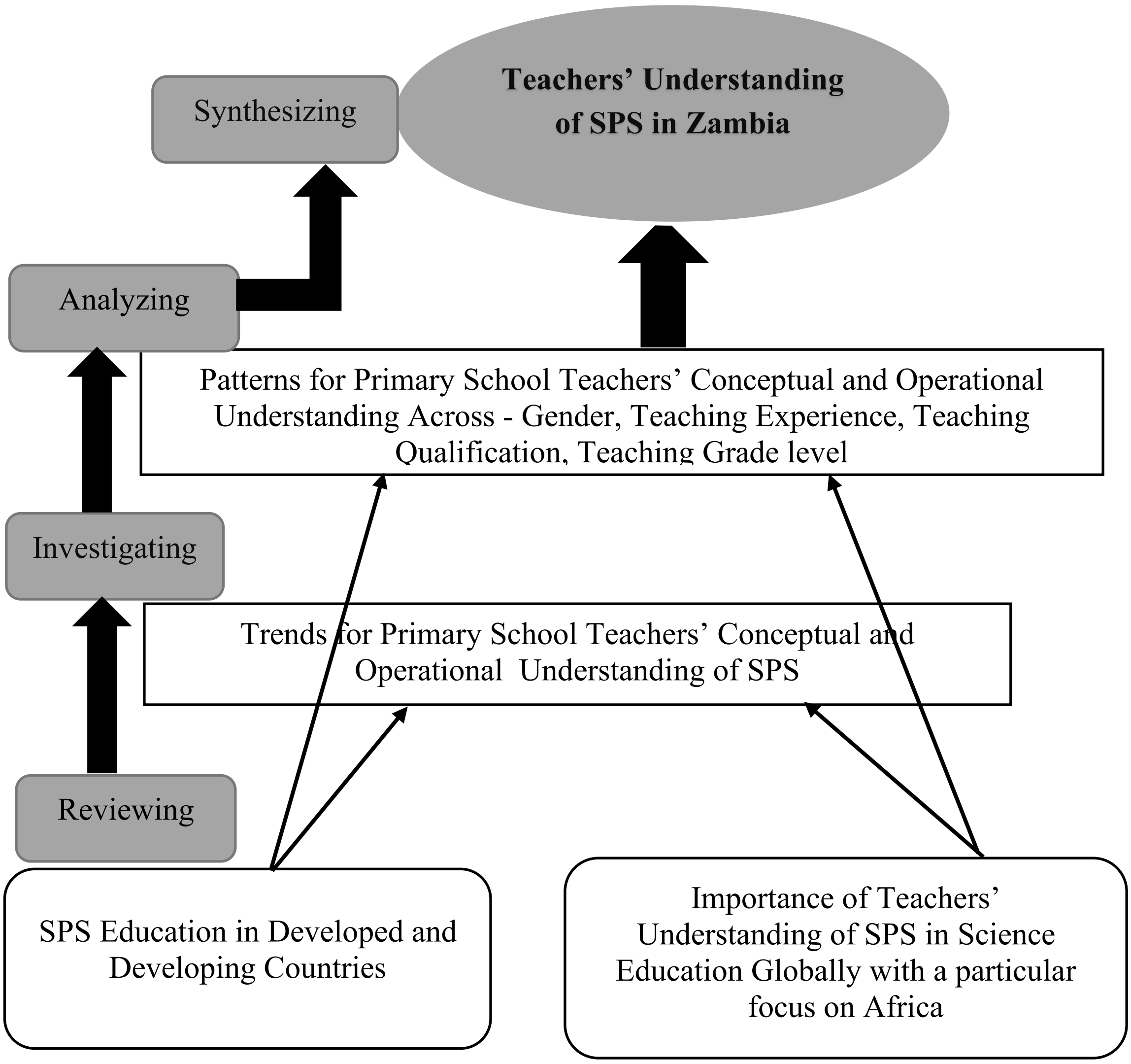
Figure 3. Diagrammatic representation of the conceptual framework



3.4 Analytical Framework

According to Chataigner (2017), analytical frameworks are a methodological ecosystem to guide and facilitate sense-making and understanding. Their application gets far ahead of humanistic situations and is deemed initial and imperative in all practical study disciplines. This study's analytical framework is constructed to structure analytic thinking and help provide the logical flow of the research study process. The model aimed to guide and facilitate sensemaking and understanding of the entire research study. It combines two factors: the theoretical framework that breaks the investigation into main components and shows the presumed association. The other factor is the conceptual framework that provides specific information on the research scope and purpose and how the problem will be explored and investigated (Chataigner, 2017).

Figure 4. Drawn Depiction of the Analytical Framework



The three frameworks outlined above help understand the study's research problem and guide the research's development, collection, and analysis. The study's need and relevance in the science education field underscores the relevant variables for this study are depicted in the conceptual framework. Then, the theoretical framework defines how this dissertation is expressed logically, epistemologically, methodologically, and analytically. Finally, the analytical framework guided and facilitated the sense-making and understanding of this research study.

CHAPTER 4: TRENDS ON SPS EDUCATION IN DEVELOPED AND DEVELOPING COUNTRIES

Chapter Overview:

This chapter provides details for research question one's purpose, the method used, design, results, and conclusion. It contributes to the logical sequence followed in investigating the problem in the study.

RQ1: What is the trend of SPS education research in developed and developing countries?

4.1. Purpose

The purpose was to analyze and evaluate the research studies conducted on science process skills (SPS) in science education in the context of developed and developing countries. This section's purpose was examined under the guiding question: (a) What is the trend on science process skills education focusing on three vantage points: science curriculum, teacher education and 21st Century Learning?

4.2. Method

The method carried out is a systematic literature review. It concerned scrutinizing and integrating studies previously done worldwide, taking into consideration the instructive importance of SPS. An integrated analysis of previous research studies on the trends studies of teachers' understanding of SPS in developed and developing countries was employed. The examination was limited to peer-reviewed journal articles written in English and whose full papers were available on the databases.

The research papers announced between 1987 and 2018 for SPS education have been predominant in inquiry since the early 1980s. The researcher assessed summaries of these articles to determine their applicability, and after the assessment procedure, 31 papers were considered for this research question. In sum, 198 documents were found due to the initial search.

4.3. Design

The study employed a qualitative literature review as a design. An organized collection of data inquisition on articles about the educational significance of SPS and teachers' understanding of SPS has in science education was carried out through some search engines (Google Scholar, ProQuest, Crossref). After that, a manual search of the online database (Acaemia.edu, Science direct and Mendeley). The examination of research studies on SPS in science education used the following disposition:

(i) examined and evaluated the significance of SPS for science education,

(ii) studied and analyzed the trend on SPS education from established and emerging countries focusing on three vantage points: science curriculum, teacher education and 21st Century Learning.

4.4. Results

Three viewpoints are the focus for presenting the results of this research question: (i) Trends on SPS education under Curriculum Perspective, (ii) Trends on SPS education under Teacher Education Perspective and (iii) Trends on SPS education under the 21st Century Learning Perspective. The country classification as developed and developing is on the United Nations Development Programmes (UNDP) Country Classification System.

The categorization criteria are from the Human Development Index (HDI) calculation, considering its multifaceted nature.

4.4.1. Results for Trends on SPS Education under Science Education Curriculum Perspective

The Organization for Economic Co-operation and Development through Programme for International Scientific Assessment (OECD-PISA) Project emphasizes that science curriculum should focus on knowledge acquisition and offer means and ways for students' operational outcomes in science education (Harlen, 1999). There are three main trend findings in this section.

The first one is the inequality of SPS inclusion in the science curriculum: research studies from developed and developing countries have identified SPS's uneven inclusion in the science curriculum and assessment activities. The second trend was the inappropriate analysis of science curriculum documents on SPS consideration as the main factor that negatively affects SPS education in the sciences teaching/learning process: Duruk et al., 2017; Downing & Gifford, 1996; Siachibila & Banda, 2018; Patonah et al., 2018. Another study findings from a developing nation point out that the variety of teaching approaches during the science learning process positively impacts SPS development Rauf et al. (2013).

Thirdly the findings on the trends in research under the science curriculum perspective on SPS focus more on the inclusion of SPS in science curriculum reference and assessment documents. The third finding is the science curriculum implementers' Behavioural influence. Attitude towards the science education of curriculum implementers such as teachers affects their performance on SPS education in the teaching and learning process Downing & Filer (1999).

One of the most important goals of the science curriculum is to develop skills that lie under scientific thinking and decision, referred to as SPS (Yumusak, 2016). The two categories of SPS, BSPS (Simpler) and ISPS (Complex), are interrelated. The BSPS are a basis for acquiring and developing the ISPS (Padilla,1990). Regularly the application of these skills is indissociable. SPS inclusion in the science curriculum allows students to create and understand scientific ideas, life operations and skills alongside physical entities through studying the environment/living things. A profound goal of SPS inclusion in the curriculum is to emphasize intellectual value rather than the importance of memorizing scientific facts or principles (Ostlund, 1992). Unfortunately, some previous studies review unbalanced inclusion and application of these skills in the science curriculum—an assertion that BSPS are more represented than ISPS ((Duruk et al., 2017). Table 4 summarizes the findings for the trend on SPS education under the science curriculum perspective.

Table 4. Trends on SPS Education under curriculum perspective

A. Developed Countries Findings, Author, Country

1. Teachers' performance in SPS can be affected by their attitude towards science (Downing & Filer, 1999) – USA.
2. Subjects whose SPS competency is high pose more critical questions and raise the usage of various/ advanced items in teaching (Downing & Filer, 1999) – USA.
3. In Japanese textbooks, BSPS are eminent in lower elementary grades (G3), and ISPS are focused more on the upper elementary school level (Lumbantobing, 2005) - Japan

B. Developing Countries Findings, Author, Country

4. There is an Insufficient display of ISPS in the science curriculum (Duruk et al., 2017) – Turkey.
5. Less inclusion of some science process skills - classifying, predicting, communicating, constructing hypotheses in the textbook (Dokme, 2005) – Turkey
6. Indonesian textbooks primarily emphasize BSPS in all grade's levels; (Lumbantobing, 2005) – Indonesia.
7. BSPS are more noticeable in the science curriculum for the Junior school level (Patonah et al., 2018) -Indonesia.
8. Teaching and learning science using several teaching methods during science classroom practice is beneficial regarding creating chances for teaching science process skills (Rauf et al., 2017) – Malaysia.
9. Examining BSPS is given more preference compared to ISPS in Chemistry Practicals (Siachibila & Banda, 2018) - Zambia

4.4.2. Results for Trends on SPS Education under Teacher Education Perspective

Under this viewpoint, the findings indicate a trend of the inadequate conceptual understanding of SPS for both in-service and pre-service teachers (Karsli et al., 2009). There is a disparity between pre-service teachers and in-service teachers' SPS understanding levels, with the in-service teachers being better (Kruea-In et al., 2015). Then, pre-service teachers' performance on SPS was reasonable compared to their theoretical knowledge (Chabalengula et al., 2012). Teacher educators' critical role in helping prospective teachers develop SPS can never be unnoticed (Molefe et al., 2016). The significant influence of short-term science education programs and peer teaching strategies on SPS development are among some significant findings (Foulds & Rowe,1996; Agoro & Akinsola, 2013). A clear presentation of the results under this perspective is in Table 5.

Table 5. Trends on SPS Education under Teacher Education Perspective

A. Developed Countries Findings, Author, Country
1. Brief courses in science education may influence significant SPS development. Nevertheless, further SPS development is needed by considering more vital treatment programs for student teachers (Foulds & Rowe, 1996) – Australia. 2. Pre-service teachers' performance on SPS was better than their conceptual understanding of the same skills. Based on their inability to provide reasonable abstract definitions and explanations of the SPS (Chabalengula, Mumba & Mbewe, 2012) – USA.
B. Developing Countries Findings, Author, Country

3. Most science teachers lack theoretical knowledge about SPS (Karsli, Şahin & Ayas, 2009) – Turkey.
4. Teacher educators play an essential role instructionally in pre-service education as their practice influences the development of students' SPS (Molefe, Stears & Hobden, 2016) - South Africa.
5. Preservice science teachers SPS in integrated science is enhanced using Reflective-Reciprocal Teaching and the Reflective-Reciprocal Peer Teaching strategies (Agoro & Akinsola, 2013) – Nigeria.
6. In-service teachers' understanding of SPS is higher than that of the pre-service teachers. Despite this, both groups' score for inferring skill is low (KrueaIn, Kruea-In & Fakcharoenphol, 2015) – Thailand
7. Elementary teacher trainees' SPS knowledgeableness is at a moderate level (Chuong, 2013) - Cambodia

SPS proficiency besides science content is a critical component of teaching science competency at any level of education. Trends under the teacher education perspective have emphasized intensive science teacher preparation on SPS development as essential in providing quality science learning in education. Teacher educators support pedagogical optimism, which benefits abstract understanding than SPS's acquiring within their practice (Molefe et al., 2016). SP

4.4.3. Results for Trends on SPS Education under the 21st Century Learning Perspective

Finding under this perspective indicate a general tendency stating the necessity of SPS education in 21^{st}-century learning. 21st-century learning is essential as it involves skills used in modern knowledge, and SPS can make the student better talented to meet the life demands of the 21st Century (Osman & Vebrianto, 2013).

One previous research study pointed out the need for people to discuss society's critical technological and scientific activities in this rapidly evolving world. The numerous tasks now require advanced knowledge, skills, and productive communication within a community, raising the need to develop SPS through science education (Soylu, 2004 in Gultepe, 2016). A need then for an education system that promotes the development of the SPS in this 21st-century era and after. "The development of science process skills enables students to solve problems, think critically, make decisions, find answers, and satisfy their concerns" (Remziye et al., 2011, p. 51). The significance of teaching students SPS "is to allow students to describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge and communicate their ideas to others" (Opara, 2011 in Abungu et al., 2014, p. 359).

Table 6. Trend on SPS Education under 21st Century Learning Perspective

Developed Countries Findings, Author, Country
1. SPS learning by students can be encouraged when using tools such as a microcomputer, using the file-management program and structured activities (Berge, 1990) – USA.
Developing Countries Findings, Author, Country

2. SPS have a significant role in science education (Demirbaş & Tanriverdi, 2012) – Turkey.
3. The SPS underlined in this research paper helped the trial classes improve in chemistry than the monitored classes (Abungu, Okere & Wachanga, 2014) – Kenya.
4. Students taught using the ICT and environment strategies obtained better results in the SPS and achievement test than students taught using the conventional technique (Osman & Vebrianto, 2013) – Indonesia.
5. 21st-century skills can be cultivated through scientific literacy and SPS corresponding to advances in technology and the blast of information in the digital age (Turiman et al., 2012) – Malaysia.

4.5. Conclusion

Established on the results, more study reports on SPS in science education appear in emerging countries than developed countries, with Turkey topping the list for developing countries. The review findings indicate the unequal presence of SPS in the science course records and the syllabus execution at all science education stages. Finally, findings reveal not many researches on SPS education about 21st Century Learning performed in advanced and emerging countries. Involved education organizations have to consider suitable and sensible adventures on teacher preparation of SPS education and the fair enclosure of SPS in the science course and its execution into regard. SPS stimulates the growth of additional abilities persons should have in this 21st-century period. So, SPS education in science schooling rests a necessity for advanced and emerging nations.

CHAPTER 5: ESSENTIALITY OF TEACHERS' UNDERSTANDING OF SPS EDUCATION FOR AFRICA

Chapter Overview

The previous chapter focused on the 'how' details for research question one. In this chapter, the intent, the method, design, results, and conclusion for research question two are offered as part of the compelling sequence followed in investigating the problem in the study.

RQ2 Why is teachers' understanding of SPS essential in science education for Africa?

5.1. Purpose

The main aim is to explore and assess research studies on teachers' understanding of Science Process Skills in science education global perspective while narrowing to the importance of the same on Africa. Two central questions guided this study section: (a) Why is teachers' understanding of science process skills essential in science education for Africa? (b) Have there been any research studies on SPS education in Africa, considering the previous research studies conducted under the science curriculum, teacher education development and the 21st Century learning perspectives?

5.2. Design

The qualitative descriptive research design is used for this particular study section.

5.3. Method

Relevant literature was retrieved between the period of December 2019 to February 2020 primarily from some search engines (Google Scholar, ProQuest, Crossref, Scopus and ERIC) using search terms ((“SCIENCE PROCESS SKILLS” AND “SCIENCE EDUCATION” AND “UNDERSTANDING” AND “21st-CENTURY LEARNING” AND “AFRICA”)).

Since way back to date, research studies on the role of teachers in facilitating scientific skills development in science education have been predominant. An independent search for key educational journals from a global perspective included publications: Journal of Educational and Social Research, American-Eurasian Journal of Scientific Research, Journal of Research in Science Teaching, International Journal of Education and Research, Journal of Education and Practice. Three key search terms, Science Process Skills, Understanding and 21st Century, Learning, were used satisfactorily to capture this review's central theme. The examination was constrained to journal papers authored in English and whose comprehensive reports were accessible on the catalogues. Furthermore, the documents circulated between the year 1980 to 2020. In total, 192 articles were found due to the primary search. The researcher assessed abstracts of these articles to determine their relevance in line with the review's objective. From this assessment process of abstracts, 60 papers are considered in this study segment.

5.4: Results

5.4.1 Why is teachers' understanding of science process skills essential in science education for Africa?

There is a critical requirement to grow individual reserves with the scientific expertise and abilities essential for modern growth in Africa. "Concerns that Africa is substantially underrepresented in the uptake of science-related courses and jobs is linked to the pedagogical practices of teachers, which are below expectations" (Sichangi (2018 in Mutende et al., 2021, p.193). A significant aspect of this dilemma is the school teacher's unreadiness to instruct these subject matter—inadequate education systems to nurture understanding and support teachers building functional instruction competencies. Prominent institutions have raised concerns about "Africa's inability to satisfy most science, technology, engineering, and mathematics (STEM) jobs within industries" (Sichangi, 2018, p.2). The deficiency of such a workforce is associated with teaching and learning practices geared towards passing examinations and not applying knowledge acquired to solve real-life societal problems.

Today's pupils need teamwork, interaction, person-value, nationality, ingenuity, and tech modernization to level the peaks of attaining viable expansion targets. Considering the skills highlighted, a need for quality science education for Africa is inevitable. This quality science education can only be delivered by teachers whose understanding of science education is at a high-ranking level not only in science content but processes too. Teachers' understanding of SPS significantly impacts the science learning practice. When teachers' understanding of SPS is sufficient, they are vested in promoting well-organized, dynamic, and operative science learning processes (Miles, 2010).

5.4.2 Have there been any research studies on SPS education in Africa, considering the previous research studies?

This section provides a combined review of research studies conducted on SPS in Non-African and African based on geographic continent location. The findings have been recorded underclasses of (1) Science Curriculum Perspective, (2) Science Teacher Education Development Perspective and (3) The 21st Century Skills Development Perspectives.

Table 7. Previous Studies on SPS Education: Curriculum Perspective in Africa vs Global

1. Duruk et al. (2017), Turkey, Non-African. Findings: There is an insufficient display of ISPS in the science curriculum.
2. Downing, J. & Filer, J. (1999), USA, Non-African. Findings: Teachers' performance in SPS can be affected by their attitude towards science.
3. Downing, J. & Gifford, V. (1996), USA, Non-African. Findings: Subjects whose SPS competency is high-level possess more critical questions and use diverse/ advanced items in teaching.
4. Siachibila, B. & Banda, J. (2018), Zambia, African. Examining BSPS is given more preference associated to ISPS in Chemistry Practicals

The review findings on the trends in research under the science curriculum perspective on SPS show that studies focused more on including BSPS in science curriculum reference and assessment documents. The two categories of SPS, BSPS (Simpler) and ISPS (Complex), are interrelated. They compliment each other to describe what is involved in SPS fully. The BSPS are a basis for acquiring and developing the ISPS (Padilla, 1990).

Ideally, the application of both BSPS and ISPS is indissociable. Unfortunately, some previous studies reveal unbalanced inclusion and application of these skills in the science curriculum. It is contended that BSPS are more represented than ISPS (Duruk et al., 2017).

Table 8. Previous Studies on SPS Education in Africa vs Global: Teacher Education Perspective

1. Foulds, W. & Rowe, J. (1996), Australia, Non-African. Findings: Brief courses in science education may affect significant SPS development. Nonetheless, a need for further SPS development by considering more vigorous treatment programs for student teachers.
2. Chabalengula, V., Mumba, F. & Mbewe, S. (2012), USA, Non-African. Findings: Preservice teachers' performance on SPS was better than their conceptual understanding of the same skills. This is based on their inability to provide reasonable conceptual definitions and explanations of the SPS.
3. Karsli, F., Şahin, Ç. & Ayas, A. (2009), Turkey, Non-African. Findings: The majority of science teachers lack theoretical knowledge about SPS.
4. Molefe, L., Stears, M. & Hobden, S. (2016), South Africa, African. Findings: Teacher educators play an essential role instructionally in preservice education as their practice influences the development of students' SPS.
5. Agoro, A, A. & Akinsola, M. K. (2013), Nigeria, African. Findings: Preservice science teachers SPS in integrated science is enhanced using Reflective-Reciprocal Teaching and Reflective-Reciprocal Peer Teaching strategies.

The review findings under this category indicate the inadequacy of the conceptual understanding of SPS for both in-service and preservice teachers (Karsli et al., 2009). There is a disparity between preservice teachers and in-service teachers' SPS understanding levels, with the in-service teachers being better (Kruea-In et al., 2012).

Then, preservice teachers' performance on SPS was reasonable compared to their theoretical knowledge (Chabalengula et al., 2012).

Table 9. Previous Studies on SPS Education in Africa vs Global: 21st Century Learning Perspective

1. Demirbaş & Tanriverdi, (2012), Turkey, Non-African. Findings: SPS have a significant role in science education.
2. Berge, Z. L. (1990), USA, Non-African. Findings: SPS learning by students can be encouraged when using tools such as a microcomputer, file-management programs, and structured activities.
3. Abungu, H. E., Okere, M. I. O. & Wachanga, S. W. (2014), Kenya, African. Findings: SPS emphasized in this study have assisted the experimental groups in performing better in chemistry than the control groups

The review findings portray that SPS still supports the development of other skills in the science teaching and learning process. Despite being in the 21st century and compared to developed countries, a teacher might be the only resource available to facilitate SPS development through 21st century learning in science for African countries.

5.5. Conclusion

With the substantial fiscal development especially undergone managed to increase socio-economic situations for the majority at the start of the twenty-first Century, the African continent is troubled by numerous interconnected vitality problems (UNESCO, 2019). Sichangi (2018 in Mutende et al., 2021, p.193) spells "a crucial need to develop human resources with the scientific knowledge and skills required for industrial development in Africa". Teachers' understanding of SPS improves learners' ability to use these skills well in daily life situations. Yet, few research studies on SPS education are from Africa compared to other continents globally.

CHAPTER 6: TRENDS AND PATTERNS OF ZAMBIAN PRIMARY SCHOOL TEACHERS' CONCEPTUAL AND OPERATIONAL UNDERSTANDING OF SPS

Chapter Overview

This chapter provides the specific research question's study purpose, method, design, results, and conclusion rationally explained. Statistically analyzed research data and relevant discussions to address research question three in this study associated with the focus of the main study problem are presented.

RQ3 What is the trend of Zambian primary school teachers' conceptual and operational understanding of SPS and the patterns across five Independent Variables?

This research question is described in two folds, i.e., the first fold focuses on trends of teachers' conceptual and operational understanding of SPS. The second is on patterns displayed across five independent variables about the dependent variables (Conceptual and Operational Understanding of SPS). The results are offered under each dependent variable (1st – Conceptual Understanding and 2nd – Operational Understanding of SPS). It should be noted that the research data used under this research question was acquired by conducting two different surveys. The first survey focused on respondents' conceptual understanding of SPS; in contrast, the second survey focused on respondents' operational understanding of SPS.

6.1. Purpose

The main intention of this study is to examine the trend of Zambian primary school teachers' conceptual and operational understanding of Science Process Skills (SPS) and patterns displayed concerning five selected variables.

6.2. Method

The descriptive statistics method analyzed the trend of teachers' conceptual and operational understanding of SPS (Dependent Variables) and patterns across Gender, teaching experience, teaching qualification and teaching grade level concerning the mentioned dependent variables.

The relationship between teachers' conceptual understanding of SPS and their SPS facilitation levels is analyzed using Bivariate Pearson Correlation. This study's teachers' SPS facilitation level refers to the regularity of teachers' teaching/learning activities that promote learners' development and acquisition of SPS**.**

6.3. Design

Associative Quantitative research method design using descriptive statistics for four independent variables and Bivariate Pearson Correlation for one Independent variable.

6.4. Sample and Sampling

Systematic Random Sampling applied in selecting eighteen (18) primary schools from the Lusaka and Central provinces of Zambia formed the study sample location as displayed in table 10 and figure 5, respectively. The sample for the first survey centred on conceptual understanding of SPS as the dependent variable consisted of one hundred (100) teachers. The second survey, whose dependent variable was operational understanding of SPS, consists of one hundred and seven (107) teachers teaching at the primary school education levels. Table 11 displays the profiles of the participants.

Sample Location

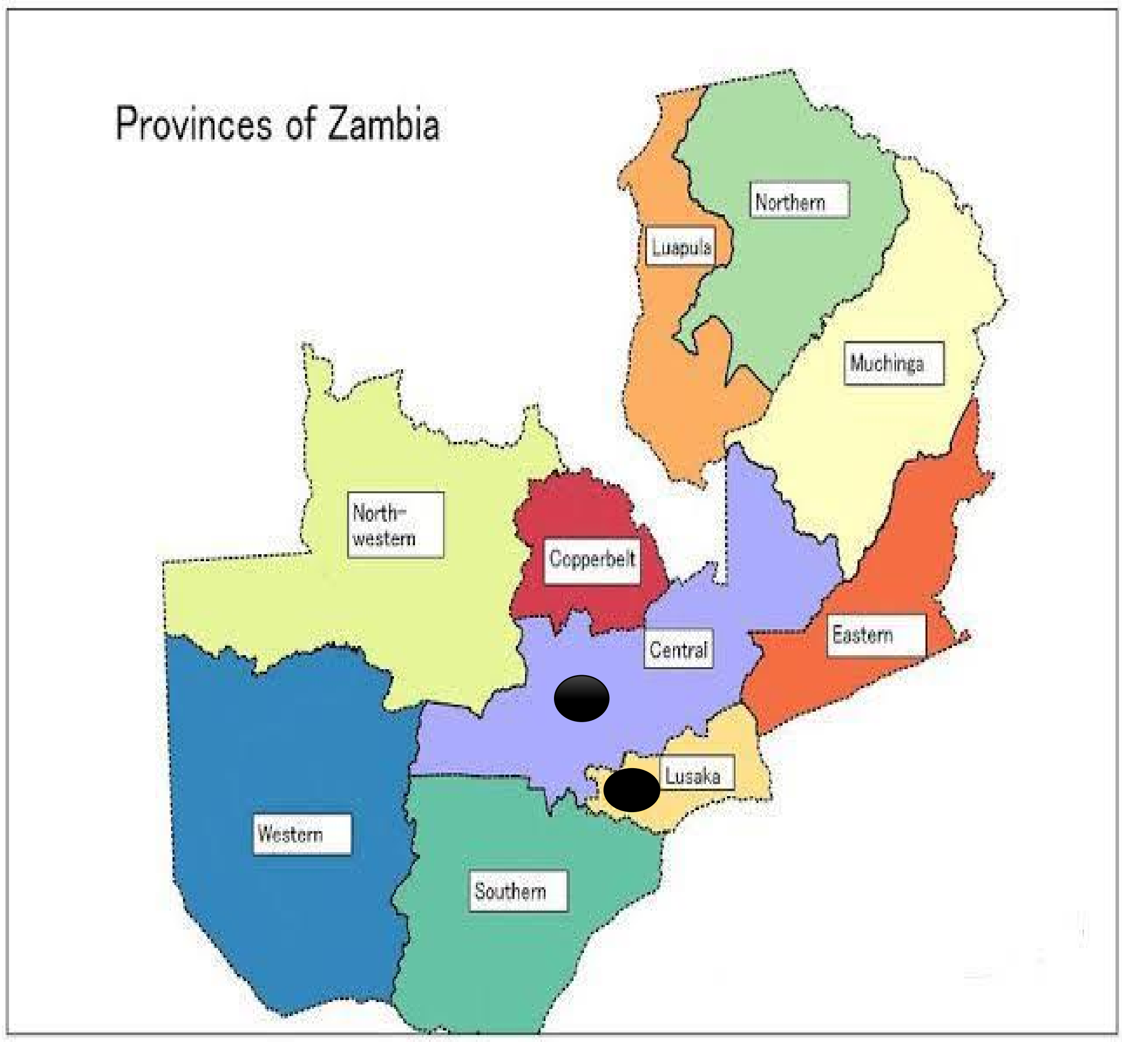


Figure 5. Location of Lusaka and Central Province in Zambia

Table 10. Name and Number of Schools for each Province

Province	Lusaka	Central
Number of Schools	8	9
Total	19	

Table 11. Participant's Demographic Information

Profile Characteristic	Category	Numerical Representation	
		1st Survey	2nd Survey
Gender	Male	21	37
	Female	79	70
	Total	**100**	**107**
Teaching Qualification	Certificate in Education	17	24
	Diploma in Education	40	61
	Degree in Education	43	22
Teaching Grade Level	Lower Primary	17	28
	Upper Primary	55	42
	Both Levels	28	37

6.5. Instrument

Data were collected using the Teachers Conceptual and Operational Understanding of Science Process Test (TCUSPT) and Teachers Operational Understanding of Science Process Skills Test (TOUSPT). Both tests had three sections.

i. The first section was intended to gather demographic information of the respondents.
ii. Section two had 12 multiple-choice conceptual/operational understanding process skills test items adapted from the 5th edition of Learning and Assessing Science Process Skills Book (Rezba et al., 2006). Some test items were adapted from instruments developed by two previous studies researchers (Burak et al.,2007, Molefe et al., 2016). Every single multiple-choice item was tallied with a specific SPS determined by the original author. Of the 12 questions, six centred on the Basic Science Process Skills (BSPS); "observe", "inference", "measure", "communicate", "classify", and "predict" (Padilla,1990, p.2). The remaining six questions focused on the Integrated Science Process Skills (ISPS); formulating hypotheses, defining operationally, identifying/controlling variables, analyzing/interpreting data,

experimenting and formulating models. Each respondent chose the corresponding process skill that pupils use in each situation. Every test item under conceptual understanding was created to assess each SPS's respondents' breadth and depth. At the same time, test items under the operational understanding of SPS were crafted to determine how respondents' would utilize their knowledge on each SPS in providing the correct response under the given situation involving SPS.

iii. Section three had 12 and 5 statements for both tests, respectively, focusing on teachers' facilitation of SPS during science teaching/learning.

6.6. Data Analysis

This part involved computing the reliability value of the conceptual and operational understanding tests.

Reliability: The tests had acceptable Cronbach alpha reliability values of 0.7 and 0.9 in that order.

Validity: To ensure the validity of the compiled tests' items, three science education experts identified each question item with its associated SPS testing.

Participants' responses to the test items were scored and categorized as correct and incorrect. A code mark 1 was allotted for the correct choice response and 0 for the wrong choice.

The coding system for teachers' SPS facilitation level participants' responses was 3- always, 2- often, 1- sometimes, and 0- never.

This study examined each SPS under two categories of science process skills to investigate participants' conceptual and operational understanding. The "basic (simpler) process skills provide a base for learning the integrated (more complex) skills" (Padilla, 1990, p.2). These skills are listed in table 12.

Table 12. SPS ID & Category for Test Question Items

No.	BSPS	No.	ISPS
1	Observe	1	Formulating hypothesis
2	Infer	2	Define operationally
3	measure	3	Identify/control variables
4	communicate	4	Analyze/interpret data
5	classify	5	Experiment
6	predict	6	Formulate models.

The two categories of process skills are arranged in a logical order of increasing sophistication (1 – 6). It is an expectation of students by the 3rd grade of primary school level to spend more time using abilities such as observation and communication. The more complex skills, i.e., the ISPS, are usually introduced to learners from their fifth grade. As students get of age, they will start to spend more time using the skills of inference and prediction. Classification and measurement will likely be used across the grade levels more evenly, partly because there are different ways to do classifying in increasingly complex ways. Methods and measuring structures should also be presented gradually to learners around time. Incorporating the simple science process skills and slowly expanding capabilities to acceptable model assessments are progressively accentuated in succeeding class stages. It is a prospect of learners by quarter grade of primary school level.

6.7. Results

6.7.1. RQ3 A: What is the trend Zambian primary school teachers' conceptual and operational understanding of SPS?

This research question results are shown in two, i.e., findings of teachers' conceptual understanding of SPS and those obtained under teachers' operational understanding of SPS compared to previous studies findings. Furthermore, the description of the results begins with a table display followed by a brief paragraph describing the tabulated information.

a. *The results and trend displayed on Zambian Primary School Teachers' Conceptual Understanding of SPS*

Table 13. Findings on Respondents' Conceptual Understanding of SPS

Rating	Science Process Skill	Mean Score
High Understanding	Experimenting	0.85
	Classification	0.81
	Communication	0.72
	Predicting	0.71
	Identifying & Controlling Variables	0.54
	Observation	0.43
	Defining Operationally	0.40
	Formulating Models	0.38
	Formulating Hypothesis	0.37
	Analyzing & Interpreting Data	0.33
	Inference	0.30
Low Understanding	Measuring	0.17

Mean Av=0.50

Table 13 indicates the Mean score results of all the 12 SPS in descending order- High to Low. Descriptive statistics from teachers' original response value on each SPS test item shows a mean range between (M=0.17 to M=0.85), giving an average mean of M=0.50. SPS Mean scores above the average mean M=0.50 fall under the High Understanding Level. In contrast, those with a Mean score below M=0.50 fall under the Low Understanding Level. The trend observed from the results is that almost all the respondents' measuring skill is deficient (M=0.17, SD=0.378) while their skill of Experimenting (M=0.85, SD=0.359) is very high. Seven skills (58%) of the 12 SPS spread relatively more in the low mean score range. This indicates that teachers' conceptual understanding of SPS is below-average, thus insufficient.

Trend: Results tendency points to a general direction. Teachers' conceptual understanding of SPS is insufficient, confirming the findings from previous studies such as Emereole (2009).

b. The results and trend displayed of Zambian Primary School Teachers' Operational Understanding of SPS

Table 14. Findings on Respondents Operational Understanding of SPS

Ranking Order	SPS ID	Mean
High Understanding	Predicting	0.93
	Classification	0.82
	Data Analysis/Interpret	0.81
	Formulating Hypothesis	0.75
	Formulating Models	0.69
	Experiment	0.68
	Identify/Control Variables	0.68
	Communicate	0.54
	Inference	0.37
	Defining Operationally	0.24
	Observation	0.00
Low Understanding	Measuring	0.00

Mean Aver=0.54

Table 14 displays all the 12 SPS mean score results in descending order-High to Low. Teachers' original response value for each Science Process Skill test item shows a mean range between (M=0.00 to M=0.93), giving an average mean of M=0.54. SPS Mean score above the average mean M=0.54 is under the High Understanding Level, SPS Mean score below M=0.50 fall under the Low Understanding Level. Eight skills (67%) of the 12 SPS spread relatively more in the high mean score range. However, none of the respondents' answers on the observation and measuring skill was correct among the four skills below the average mean score.

Trend: Results tendency points to a general direction

Teachers' operational understanding of SPS is relatively above average; thus, it can be deemed as reasonable to confirm the findings from previous studies such as Hafizan et al. (2012).

6.7.2. RQ3 B: What are the patterns of Zambian primary school teachers' conceptual and operational understanding of SPS across five Independent Variables (Gender, teaching experience, teaching qualification, teaching grade level and teacher facilitation level of SPS?

RQ3-B1 (a): Teachers' Conceptual Understanding of SPS across Gender

***Null Hypothesis*:** There's no significant difference in Zambian primary school teachers' conceptual understanding of SPS across genders.

Table 15. Group Statistics for Respondents' Conceptual Understanding across Gender

Group Statistics					
Gender		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Conceptual Understanding	Male	21	.52	.17	.04
	Female	79	.50	.19	.02

The group statistical results shown in table 15 above display mean score for females (0.50) is slightly less than for males (0.52), while the Standard deviation shows the inverse.

Statistical Results:

An independent t-test did not report a significant difference between respondents' conceptual understanding of SPS test scores for males (M=0.52, SD=0.17) compared to females (M=0.52, SD=0.17; t(98)=.418, p=>.005), and a small effect was found d=0.1. Hence null hypothesis is accepted.

Pattern: Non repeated occurrence. Results of the study are inconsistent with results of similar studies previously conducted stating that teachers' conceptual understanding of SPS differs across gender groups, e.g., Aydoğdu et al., (2014).

RQ3 B2(a): Teachers' Conceptual Understanding of SPS across Teaching Experience

Null Hypothesis: There's no significant difference in teachers' conceptual understanding of SPS across teaching experience.

Figure 6. Respondent' Conceptual Understanding of SPS Mean Scores across Gender

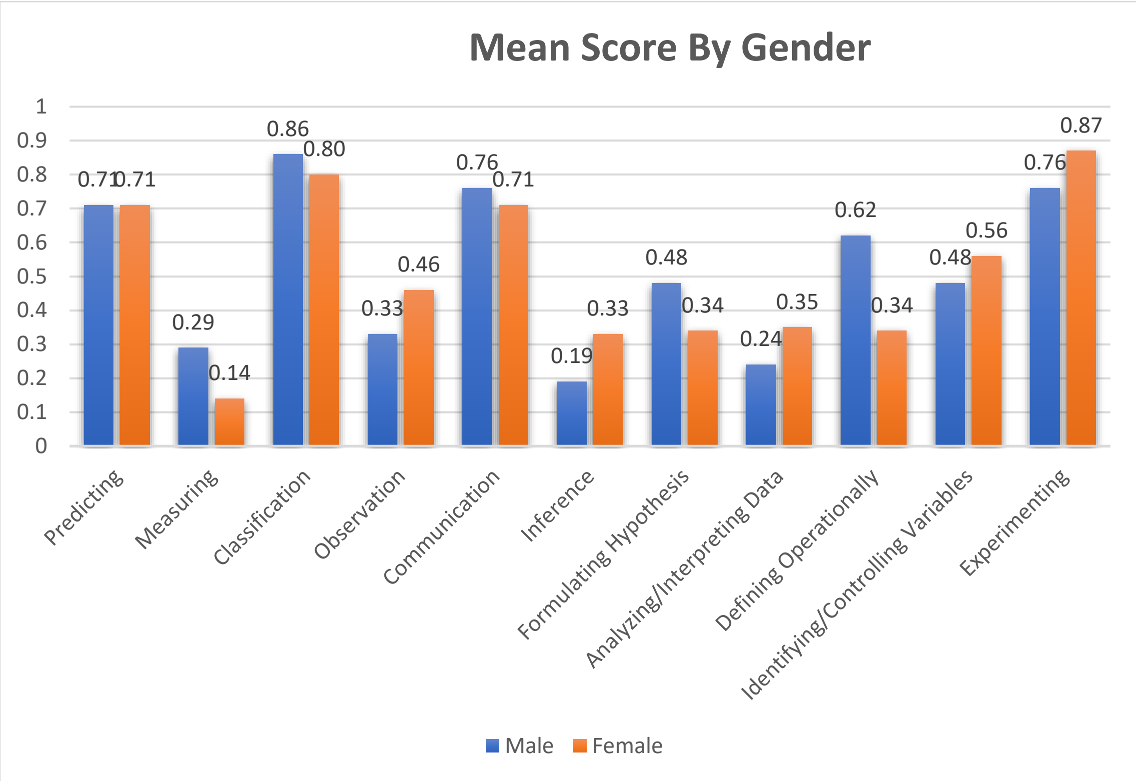


Table 16. Statistical Results on Teaching Experience Variable

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
1-5	6	**.60**	**.24**	.10	.34	.85	.17	.92
6-10	17	**.56**	**.25**	.06	.44	.69	.17	.92
11-15	25	**.47**	**.18**	.04	.40	.54	.17	.92
16-20	18	**.47**	**.13**	.03	.41	.54	.17	.67
21-25	18	**.51**	**.18**	.04	.42	.60	.17	.83
≥26	16	**.47**	**.14**	.03	.40	.54	.33	.75
Total	100	**.50**	**.18**	.02	.46	.54	.17	.92

Statistical Results:

The group differences examined using ANOVA found teachers with 1-5 years of experience in teaching had a higher mean score (M=0.60, SD=0.24) in comparison to the other five categories. The results showed no significant difference in teachers conceptual understanding of SPS regarding teaching experience (F (5,94) = 1.052, $p>0.05$) and the actual mean difference between the teaching experience category was comparatively small $\eta^2 = 0.1$.

Pattern: Non repeated occurrence. The results differ from previous research findings stating that elementary school teachers' science process skill scores differed significantly by gender and seniority, such as Aydoğdu et al., (2014).

RQ3 B3(a)Teachers' Conceptual Understanding of SPS across Teaching Qualification

Null Hypothesis: There's no significant difference in teachers' conceptual understanding of SPS across teaching qualifications

Table 17. Descriptives on Conceptual Understanding of SPS across Teaching Qualification

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Min	Max
Certificate in Education	17	**.65**	**.21**	.05	.54	.76	.33	.92
Diploma in Education	55	**.44**	**.15**	.02	.40	.48	.17	.83
Degree in Education	28	**.53**	**.18**	.03	.46	.60	.17	.83
Total	100	**.50**	**.18**	.02	.46	.54	.17	.92

Group differences examined using ANOVA found teachers with a Certificate qualification in teaching had a higher mean score (M= 0.65, SD= 0.21), compared to those with Degree qualification (M=0.53, SD=0.18) who were higher than teachers with Diploma qualification (M=0.44, SD=0.15); $F(2,97) = 10.56$, $p<0.05$. Since the Levene statistics were significant and equal variance was not assumed, Dunnett T3 was selected when conducting Post Hoc Test analysis. Ensuing below in table 18 are statistical results obtained after performing the Post Hoc Test analysis.

Table 18. Post Hoc Results – Multiple Comparisons

Dependent Variable: Conceptual Understanding
Dunnett T3

(I) Teaching QL		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Certificate	Diploma	.21105*	.05484	**.00**	.07	.35
Diploma	Degree	-.08588	.03983	**.10**	-.18	.01
Degree	Certificate	-.12518	.06174	**.14**	-.28	.03

*. The mean difference is significant at the 0.05 level.

Statistical Results:

The test indicated that the mean score of the teachers with a certificate qualification (M= 0.65, SD= 0.21; $F = 10.56$, $p<0.05$ was high in comparison to the other two qualification categories with mean scores (Diploma M=0.44, SD=0.15), and (Degree M=0.53, SD=0.18). The conceptual understanding of SPS of the teachers with a degree qualification in education (M=0.53, SD=0.18; $F=10.559$, $p>.05$) was not significantly different from certificate and diploma holders. Meanwhile, a significant difference between teachers with a certificate and diploma qualifications was recorded (Certificate M=0.65, SD= 0.21, Diploma M=0.44, SD=0.15; F=10.56, p<.05). Despite reaching statistical significance, the actual mean difference between the teaching qualification categories was relatively small ($\eta^2 = 0.2$)

Pattern: Repeated occurrence. Results of the study on the teaching qualification variable are consistent with results of similar studies previously conducted revealed that teachers' understanding of SPS differed by teaching qualification, such as that of Shahali et al. (2017).

The findings on this variable are exceptional. Usually, teachers with a higher education qualification are likely to have better results than those with a lower education qualification. However, findings in this study on this specific variable are different. The researcher conducted an interview session to substantiate the rare result -teachers with certificate qualifications outperform the SPS test's diploma qualification.

Interview Process

An interview is considered a verbal exchange or talk between the researcher and individual participants of the research. This method helps gather data on attitudes, values, and opinions and produce data quickly.

Participants: 5 Respondents (2 Male and 3 Females), selected purposively/conveniently from the survey sample location.

Methodology: Qualitative Thematic Content Analysis.

Method: Semi-structured Interview (Arksey & Knight, 1999).

Tool: Interview Schedule.

(A) Demographic Information

Table 19. Respondents' Demographic Information

Teacher ID	Gender	Yrs. in Service	Teaching Qualification	Teaching Grade Level/Subject Specialization
1	F	22	Certificate and Degree in Primary Teaching	Both Primary Levels + Junior Sec (Specialized in Science Teaching).
2	M	16	Certificate in Primary Teaching + Diploma in SEN	Both Primary Levels + Junior Sec (Specialized in Special Education Needs).
3	M	3	Degree in Primary Teaching	Both Primary Levels + Junior Sec (Specialized in Agriculture Science).
4	F	1	Diploma in Primary Teaching	Both Primary Levels + Junior Sec (Specialized in Social Sciences and English Language).
5	F	11	Degree in Primary Teaching	Both Primary Levels + Junior Sec (Specialized in Mathematics Teaching).

(B) Interview Schedule

Table 20. Interview Schedule Contents

Focus Area	Questions and Probes
A. Demographic Information	1. What are your names? 2. How long have you been teaching? 3. Which grade level(s) have you been teaching? 4. What is your teaching qualification?
B. Conceptual Understanding of Science Process Skills (SPS)	1. What do you understand by SPS? 2. How do you rate your understanding level of SPS?
C. Perceptions/Perspectives of Teaching Qualification and Teachers' Understanding of SPS.	1. Does teaching qualification bear any influence on a teacher's understanding of SPS? 2. How would you explain a case where certificate holders outperform degree or diploma holders in an SPS test?

(C) Interview Responses

Table 21. Individual Respondents' Perceptions/Perspectives on Focus Question

Focus Area	Responses (*Recorded regarding Teacher's ID)*
Conceptual Understanding of SPS **Question:** *What do you understand by SPS?*	1. These are cognitive skills. 2. Content knowledge of science, e.g., filtration, can be a skill and a process. 3. Teaching procedure/methodologies. 4. Skills used when teaching science, e.g., observation BSPS, are simple ways, but as for ISPS, "I do not have much experience." 5. Experiments and process of teaching.
Perceptions/Perspectives of Teaching Qualification and Teachers' Understanding of SPS. **Questions:**	
1. Does teaching qualification influence a teacher's understanding of SPS?	1. On content knowledge but not teaching methodology 2. No 3. Not always 4. Teaching qualification does not determine the level of understanding; its interest in the subject area matters most. 5. From experience, qualification bears less influence on teacher's level of SPS understanding due to various factors such as period of training, subject specialization, and individual interest.
2. How would you explain a case where certificate holders outperform degree or	1. Certificate holders are more knowledgeable about SPS

diploma holders in the SPS test?	2. Specialization makes it easier for teachers to focus on what/how of teaching. 3. Challenging to focus on SPS because classroom activities are examination-oriented. Experience is based on each level, and high qualification training focus on advanced content and ignore the primary content. 4. It might be that those with higher qualifications in teaching's understanding level was insufficient. The teachers' qualification upgrading is done for position and or promotion's sake training received at certificate level is suitable for primary school teaching covering all subjects. 5. Quality time spent on research and practice by teachers. Usually, teachers obtain higher teaching qualifications for salary increments, not upgrading knowledge.

(D) Interview Response Labelling and Summary

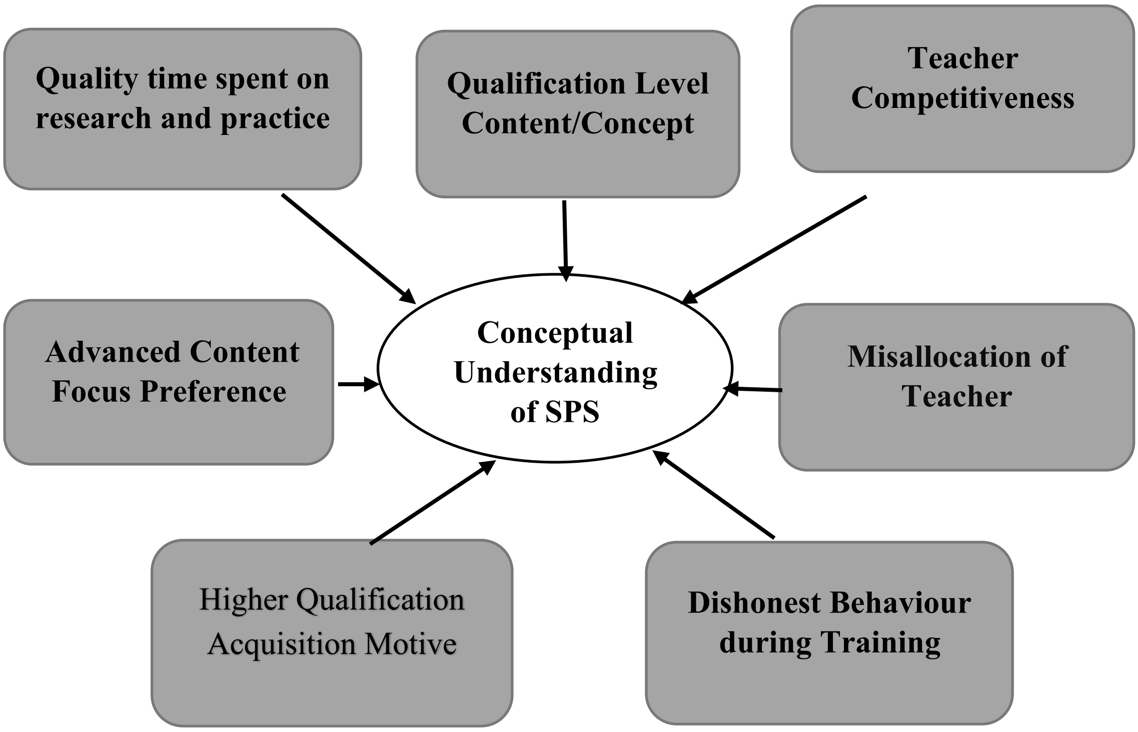


Figure 7. Diagrammatic structure on Interview Results

Summary on Interview Results: Rare Finding Reasons for teachers with certificate qualifications outperforming the diploma/degree qualification in the SPS test include the following.

- Training received at certificate level is suitable for primary school teaching. It covers pedagogical content for a year and all primary school subjects during pre-service teaching practice for another year.
- Quality time is spent on research and practice by teachers during certificate training.
- Motive (salary increment/promotion) behind higher qualification acquisition affects teacher understanding of SPS.

RQ3 B4(a) Teachers' Conceptual Understanding of SPS across Teaching Grade Levels

Null Hypothesis: There's no significant difference in teachers' conceptual understanding of SPS across teaching grade levels.

Table 22. Descriptive Results on Teachers' Conceptual Understanding of SPS across Teaching Grade Levels

					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Dev**	Std. Error	Lower Bound	Upper Bound	Min	Max
Lower	17	**.42**	**.15**	.04	.34	.50	.17	.75
Upper	40	**.48**	**.17**	.03	.43	.54	.17	.92
Both	43	**.55**	**.20**	.03	.49	.61	.17	.92
Total	100	**.50**	**.18**	.02	.46	.54	.17	.92

The differences examined using ANOVA found that teachers teaching both grade levels have a higher Mean Score (M= 0.55, SD= 0.20) than the Mean Scores for Upper Primary Level (M=0.48, SD= 0.17) teachers whose score is higher than that for Lower Primary Level (M=0.42, SD= 0.15; ($F(2,97)=3.32$, $p<0.05$). Test of Homogeneity of variances displayed Levene Statistics = $p>0.05$.

Table 23. Post Hoc Results

Multiple Comparisons

Dependent Variable: Conceptual Understanding

Tukey HSD

(I) Teaching GL		Mean Difference (I-J)	Std. Error	**Sig.**	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Lower	Upper	-.06176	.05230	.47	-.19	.06
	Both	-.12688*	.05175	**.04**	-.25	.00
Upper	Lower	.06176	.05230	.47	-.06	.19
	Both	-.06512	.03968	.23	-.16	.03
Both	**Lower**	**.12688***	**.05175**	**.04**	**.00**	**.25**
	Upper	.06512	.03968	.23	-.03	.16

*. The mean difference is significant at the 0.05 level.

Statistical Results:

The Post Hoc Test results approve a significant difference in primary school teachers' conceptual understanding of SPS across teaching grade levels. There is a significant difference between teachers teaching lower grade levels and those for both—meanwhile, upper-grade levels ($p>0.05$) recorded a non-significant difference. Despite reaching statistical significance, the actual mean difference between teaching grade-level groups was relatively small (Ƞ2). Therefore, the null hypothesis is rejected.

Pattern: Non repeated occurrence. Similar previous studies have focused on teaching grade-level variables with preservice teachers and pupils but not in-service teachers.

RQ3 B4 (a) Teachers' Conceptual Understanding of SPS across Teachers' Perspective on SPS Facilitation Levels

Null Hypothesis: There's no significant association between teachers' conceptual understanding of SPS and their Perspective on SPS Facilitation Levels.

Table 24. Teacher Conceptual Understanding of SPS and Perception/Perspective on SPS Facilitation Correlation Results

Correlations			
		SPS Facilitation	Conceptual Understanding
SPS Facilitation	Pearson Correlation	1	**-.292****
	Sig. (2-tailed)		**.003**
	N	100	100
Conceptual Understanding	Pearson Correlation	**-.292****	1
	Sig. (2-tailed)	**.003**	
	N	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

Statistical Results:

Bivariate Pearson Correlation results show a negative association (r= -0.292) between teachers' conceptual understanding and their SPS facilitation level. There is an insignificant association between primary school teachers' conceptual understanding and their facilitation levels of SPS.

Pattern: Repeated Occurrence. Results obtained supported by some studies that science teachers involved in facilitating SPS learning still had some difficulties planning, executing, and enabling SPS student assessment, e.g., Permanasari et al. (2013).

RQ3-B1 (a): Teachers' Operational Understanding of SPS across Gender

Null Hypothesis: There's no significant difference in Zambian primary school teachers' conceptual understanding of SPS across genders.

Table 25. Group Statistics Results for Respondents' Operational Understanding across Gender

Group Statistics						
Gender		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Operational Understanding	Male	37	.64	.23	.04
	Female	70	.49	.30	.04

The group statistical results shown in table 25 indicate mean score for males (0.64) is comparatively higher than for females (0.49), while the Standard deviation shows the reversal.

Figure 8. Respondents' Operational Understanding of SPS Mean Scores across Gender

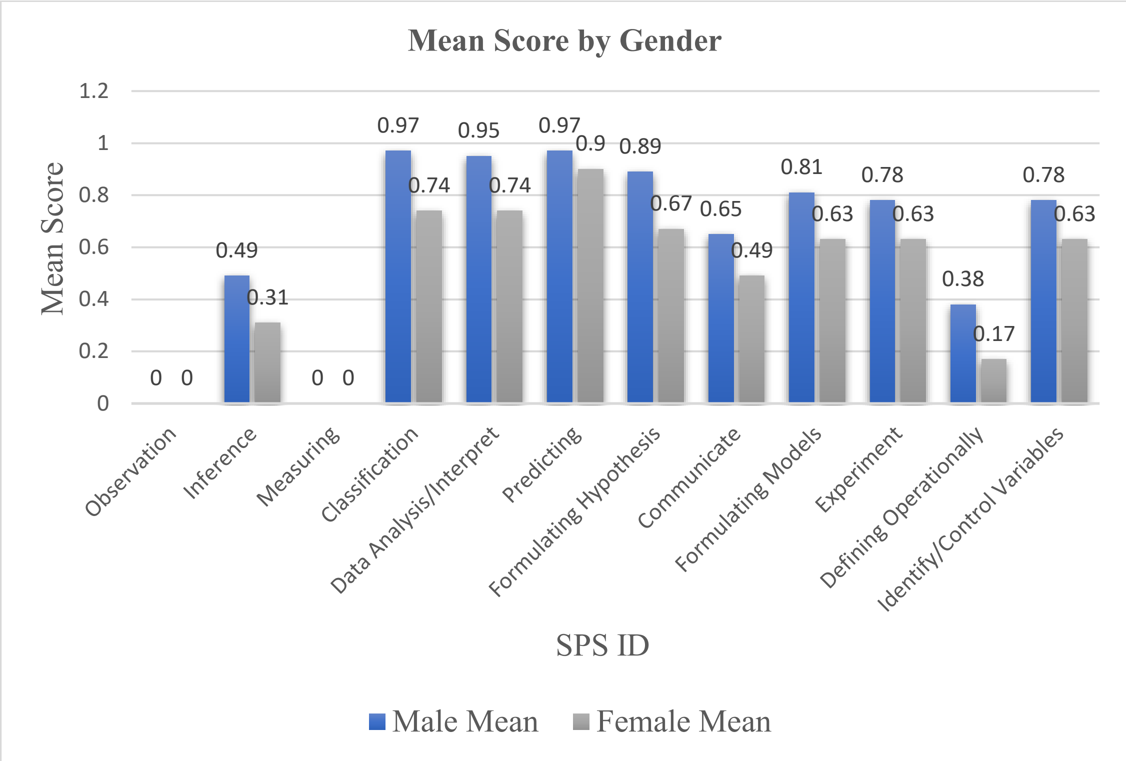


Table 26. Independent Sample t-Test on Gender Variable

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	**Sig. (2-tailed)**	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Operational Understanding	Equal variances assumed	13.37	**0.00**	2.57	105.00	0.01	0.15	0.06	0.03	0.26
	Equal variances not assumed			2.81	93.06	**0.01**	0.15	0.05	0.04	0.25

Levene's Test results: $p<0.05$

Effect Size Statistical Results (Independent t-test)

Table 27. Calculation of Cohen's d

Group 1 - Male	Male 2 - Female
Mean (M): 0.64	Mean (M): 0.49
Standard Deviation (SD): 0.23	Standard Deviation (SD): 0.30
Sample size (N): 37	Sample Size (N): 70

Cohen's d = (0.49 - 0.64)/ 0.267301 = 0.561164

Statistical results:

Statistical results from the Independent sample t-Test display a significant difference in teachers' operational Understanding of SPS across gender. The results are shown in Table 27. The mean score for male respondents (M=0.64, SD=0.23, is higher than for females (M=0.49, SD=0.30). A significant difference (t (13.37)=2.57, Sig.= $p<0.05$), with medium effect size, was found (d=0.6) in teachers' operational understanding of SPS across gender is spotted. Hence, the null hypothesis is rejected.

Pattern: Repeated occurrence. Results of the study are consistent with results of similar studies previously conducted stating that teachers' operational understanding of SPS differs across gender groups, e.g., Bulent (2015).

RQ3 B2(b): Teachers' Operational Understanding of SPS across Teaching Experience

Null Hypothesis: There's no significant difference in teachers' operational understanding of SPS across teaching experience

Table 28. Descriptive on Teachers' Operational Understanding of SPS across Teaching Experience

Descriptives								
					95% Confidence Interval for Mean			
Years in Service	N	**Mean**	**Std. Deviation**	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
1-5yrs	21	**.57**	**.28**	.06	.44	.69	.00	.83
6-10yrs	32	**.55**	**.28**	.05	.45	.65	.00	.83
11-15yrs	31	**.55**	**.30**	.05	.44	.65	.00	.83
16-20yrs	14	**.50**	**.31**	.08	.32	.68	.00	.83
21-25yrs	7	**.46**	**.36**	.14	.13	.80	.00	.83
26Above	2	**.75**	**.12**	.08	-.31	1.81	.67	.83
Total	107	**.54**	**.29**	.03	.49	.60	.00	.83

Teachers with 26yrs & above experience in teaching have a higher mean score (M= .75, SD= .12), while those whose teaching experience ranging 21-25yrs display a lower mean score (M= .46, SD= .36).

Statistical Results:

Test of Homogeneity of Variances indicates that Levene Statistics' p-value (=>0.05) is not significant. Hence, equal variances are assumed when conducting the Post Hoc Test. ANOVA results display an insignificant difference in teachers operational understanding of SPS regarding teaching experience ($F(5,101) = 0.396$, $p>0.1$). Null hypothesis accepted.

Pattern: Non repeated occurrence. Results of the study are inconsistent with results of similar studies previously conducted stating that teachers' operational understanding of SPS differs significantly by seniority (e.g., Aydoğdu et al., 2014).

RQ3 B3(b) Teachers' Operational Understanding of SPS across Teaching Qualification

Null Hypothesis: There's no significant difference in teachers' operation understanding of SPS across teaching qualifications

Table 29. Descriptive Results on Teachers' Operational Understanding of SPS across Teaching Qualification

					95% Confidence Interval for Mean			
Qualification Category	N	**Mean**	**Std. Deviation**	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Certificate	24	**.57**	**.29**	.06	.45	.70	.00	.83
Diploma	61	**.57**	**.26**	.03	.50	.63	.00	.83
Degree	22	**.45**	**.34**	.07	.30	.60	.00	.83
Total	107	**.54**	**.29**	.03	.49	.60	.00	.83

Table 29 displays descriptive statistical results on the teacher qualification variable. Teachers with Degree in teaching qualifications have a lower mean score (M= 0.45, SD= 0.34), in comparison to the other two qualification categories with equal Mean Scores (Diploma M=0.57, SD=0.26), and (Certificate M=0.57, SD=0.29). ANOVA results had ($F(2,104) = 1.46$, $p>0.05$).

Test of Homogeneity of Variances indicates that Levene Statistics' p-value = <0.05 is statistically significant. Hence, equal variances are not assumed. Post Hoc Test results have been presented in Table 30.

Table 30. Post Hoc Result on Teaching Qualification Variable

Dependent Variable: Operational Understanding
Dunnett T3

(I) Teaching Qualification		Mean Difference (I-J)	Std. Error	**Sig.**	95% Confidence Interval Lower Bound	Upper Bound
Certificate	Diploma	.01	.07	**1.00**	-.16	.18
	Degree	.12	.09	**.49**	-.11	.36
Diploma	Certificate	-.01	.07	**1.00**	-.18	.16
	Degree	.11	.08	**.41**	-.09	.32
Degree	Certificate	-.12	.09	**.49**	-.36	.11
	Diploma	-.11	.08	**.41**	-.32	.09

Statistical Results:

The Post Hoc Test results showed no significant difference ($p>0.05$) in teachers operational understanding of SPS across teaching qualifications. Therefore, the null hypothesis is accepted.

Pattern: Non repeated occurrence. The result differs from some previous research findings indicating that science process skill scores on operational understanding for elementary school teachers differed significantly by teachers' qualification, e.g., Shahali et al., (2017).

RQ3 B4(b) Teachers' Operational Understanding of SPS across Teaching Grade Levels

Null Hypothesis: There's no significant difference in teachers' operational understanding of SPS across teaching grade levels.

Table 31. Descriptive Results on Teachers' Operational Understanding of SPS across Teaching Grade Levels

Operational Understanding								
					95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	Std. Error	Lower Bound	Upper Bound	Min	Max
Lower	28	**.58**	**.29**	.05	.47	.69	.00	.83
Upper	42	**.60**	**.25**	.04	.52	.68	.00	.83
Both	37	**.45**	**.31**	.05	.35	.56	.00	.83
Total	107	**.54**	**.29**	.03	.49	.60	.00	.83

In table 31, statistically, the upper-grade level teachers have a higher mean score (M=0.60, SD=0.25) followed by the lower grade level category whose mean score is slightly below (M=0.58, SD=0.29), and the lowest mean score is for teachers teaching both grades (M=0.45, SD=0.31). The Test of Homogeneity of variances displayed Levene Statistics = $p<0.05$ while the ANOVA results had ($F(2,104)=2.94$, $p<0.05$).

Table 32. Post Hoc Results

Multiple Comparisons						
Dependent Variable: Operational Understanding Tukey HSD						
					95% Confidence Interval	
(I) Teaching Grade Level		Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Lower	Upper	-.01389	.06903	**.98**	-.18	.15
Primary	Both	.13063	.07087	**.16**	-.04	.30
Upper	Lower	.01389	.06903	**.98**	-.15	.18
Primary	Both	.14452	.06379	**.07**	-.01	.30
Both Levels	Lower	-.13063	.07087	**.16**	-.30	.04
	Upper	-.14452	.06379	**.07**	-.30	.01

Statistical Results:

The Levene Statistics p-value is statistically significant ($p<0.05$). Hence, equal variances is not assumed when performing the Post Hoc Test. there is no significant difference in teachers operational understanding of SPS regarding teaching grade levels ($p>0.05$), seeing the statistical results presented in Table 26 above. Null hypothesis accepted.

Pattern: Nonoccurrence. Previous studies have focused on teaching grade-level variables with preservice teachers and pupils but not in-service teachers (e.g., Farsakoglu et al., 2012 & Özgelen, 2012).

RQ3 B4 (b) Teachers' Operational Understanding of SPS across Teachers' Perspective on SPS Facilitation Levels

Null Hypothesis: There's no significant association between teachers' Operation understanding of SPS and their Perspective on SPS Facilitation Levels.

Table 33. Teacher Operational Understanding of SPS and Perception/Perspective on SPS Facilitation Correlation Results

Correlations			
		SPS Facilitation	Operational Understanding
SPS Facilitation	Pearson Correlation	1	**.000**
	Sig. (2-tailed)		**.997**
	N	107	107
Operational Understanding	Pearson Correlation	**.000**	1
	Sig. (2-tailed)	**.997**	
	N	107	107

Statistical Results: Pearson product correlation of teachers' operational understanding of SPS and their self-efficacy for SPS facilitation level was zero association and statistically not significant ($r= 0.00$, $p \geq 0.05$).

Pattern: Repeated occurrence. Some previous studies support that teachers' operational understanding of SPS is low. Science teachers involved in facilitating SPS learning still had some difficulties planning, executing, and facilitating SPS student assessment (Permanasari et al., 2013).

6.8. Conclusion

Trends of teachers' conceptual understanding of SPS: Results tendency points to a general direction. Participants' results indicate their conceptual understanding of SPS being below-average score. The statistical results displayed 58% of the 12 SPS spread relatively more in the low mean score range.

Trends of teachers' operational understanding of SPS: Statistically, 67% of the 12 SPS spread relatively more in the high mean score range. The trend is repeated compared to previous studies (such as Hafizan et al., 2012) on this variable.

Teachers' conceptual understanding of SPS across five (5) independent variables: Of the five variables (gender, teaching experience, teaching qualification, teaching grade level and teachers' perspective of SPS facilitation), a significant difference is verified for teachers' conceptual understanding across teaching qualification. Despite reaching statistical significance, the actual mean difference between the teaching qualification categories for their conceptual understanding of SPS was relatively small ($\eta 2= 0.2$).

Surprisingly, the statistical results displayed high SPS test scores for teachers with lower qualifications than those with a more elevated teaching qualification. Having noted that findings on this variable are unique, usually, teachers with a higher education qualification are likely to outperform those with a lower education qualification in a test scenario. But the case with the findings in this study on this specific variable is reverse as teachers with certificate qualifications' performance was better than those holding a higher qualification in the SPS test. Rare finding reasons for teachers with certificate qualifications outperforming the diploma/degree qualification in the SPS test include the following: training received at certificate level is suitable for primary school teaching covering all subjects. The other is that teachers spend quality time on research and practice during certificate training. Another was that the motive (salary increment/promotion) behind higher qualification acquisition affects teacher understanding of SPS.

Teachers' operational understanding of SPS across five (5) independent variables: Teachers' operational understanding of SPS across gender was substantial, with a medium effect size found (d=0.6). As for the teaching grade-level variable, a nonoccurrence pattern is realized in teachers' operational understanding of SPS. Lastly, participants' operational understanding across the teacher SPS facilitation level variable reflects previous research findings that repeat identifiable

CHAPTER 7: OVERALL DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

Chapter Overview

Throughout this chapter, the summary discussions for the findings have been supplied. It ends with the conclusion and recommendations.

8.1 Overall Discussion of Results

8.1.1 Summary discussion for RQ1

(i) Curriculum Perspective:

Research trends in studies on SPS in science education under the curriculum perspective highlights various cardinal issues ranging from classroom activities to assessment procedures. The OECD PISA Project emphasized that the science curriculum must focus on school and offer students' operational outcomes due to their science education (Harlen, 1999). There are three (3) main trend findings under this perspective. First, research studies from both developed and developing countries have identified the uneven inclusion of SPS in the science curriculum and assessment activities, and inappropriate analysis of science curriculum documents on SPS consideration in developed countries outnumber those from developing ones. The disproportionate presence of SPS in the science program records and through the program application at all the stages of science schooling.

(ii) Teacher Education Perspective:

SPS proficiency besides science content is a critical component of teaching science at any level of education. Trends in research under the teacher education perspective have emphasized intensive science teacher preparation on SPS development as crucial in providing quality science learning in education.

Teacher trainers support pedagogical optimism, which benefits the development of abstract understanding rather than acquiring SPS within their practice (Molefe et al., 2016). A trend on inadequacy understanding of SPS for both in-service and preservice teachers remained documented in the literature. The remarkable effect of short-term science education programs and peer teaching strategies on SPS development was another finding stated in previous studies.

(iii) 21st Century Learning Perspective:

SPS development through science learning is a requirement even in this age of time, and SPS can make the student better talented to meet the life demands of the 21st Century (Osman & Vebrianto, 2013). Trends from previous studies disclose that SPS still champions the development of other skills in the science teaching and learning process thus must not be overlooked in this 21st-century learning era. SPS is an essential key factor that influences not only one's education but also how well acquired and developed individuals can make positive contributions to economic developments in this 21st-century and future life. 21st-century learning is all but relations amongst concept and training, persons and societies, proper and informal education, pupils, and meta-intellectual advisors (Lee & Hung, 2012).

Compared to developed countries, a teacher might be the only resource available to facilitate SPS development through 21st Century learning in science for students in many parts of developing countries (Mushani, 2021). SPS still champions the development of other skills in science teaching, and the learning process thus must not be overlooked in this 21st-century learning era. Nevertheless, only a limited number of studies on SPS education with 21st Century Learning have remained carried out.

8.1.2 Summary discussion for RQ2

In the 21st period, globalization is chiefly changed by speedy science and technological innovation (Osman et al., 2009). The enormous knowledge and interdisciplinary is improving and increasing so fast due to showing off new ideas worldwide. Hence, it is necessary to educate persons to get essential and precise information rather than educate the didactic system's complete information. In effect, the science process skills (SPS) are crucial in attaining a helpful insight, which is essential for scientific inquiry as part of intellectual and probing abilities (Shahali, 2010; Kruea-In in Buaraphan, 2014). A crucial requirement is to build a workforce with logical expertise and competencies for modern improvement in Africa, but learners' education attainments in arithmetic and science stay still (Sichangi, 2018). The main contributing factor to this problem is the teacher's unpreparedness to teach these subjects—no good training programs to nurture knowledge on the topics and help educators develop practical teaching skills. “Today's students require collaboration, communication, self-efficacy, citizenship, creativity, and tech innovation to scale achieving sustainable development goals” (Sichangi, 2018, p.3).

The necessity for quality science education for Africa is evident enough. Prominent institutions have raised concerns about “Africa's inability to fill most science, technology, engineering, and mathematics (STEM) jobs within industries” (Global Partnership for Education, 2018, p.2). Results reveal hardly any research on teachers' understanding of SPS advancement in science performed in African nations (Mushani, 2021b). Provision of quality science education will be possible if teachers' understanding of science education is high in science content and processes (Mushani, 2021b). Teachers' understanding of SPS significantly impacts the science learning process. When teachers' understanding of SPS is high-level, they are empowered to promote well-organized, dynamic, and operative science learning processes (Miles, 2010).

Table 34. An Extract of SPS Education Research Studies in Africa

Author/Year/	Country	Findings
Siachibila, B. & Banda, J. (2018)	Zambia	Examining BSPS is given more preference compared to ISPS in Chemistry Practicals.
Molefe, L., Stears, M. & Hobden, S. (2016)	South Africa	Teacher educators play an essential role instructionally in preservice education as their practice influences the development of students' SPS.
Agoro, A, A. & Akinsola, M. K. (2013)	Nigeria	Preservice science teachers SPS in integrated science is enhanced using Reflective-Reciprocal Teaching and Reflective-Reciprocal Peer Teaching strategies.
Abungu, H. E., Okere, M. I. O. & Wachanga, S. W. (2014) Kenya	Kenya	“Science process skills emphasized in this study have assisted the experimental groups in performing better in chemistry than the control groups” (Abungu et al., 2014, p.42).

8.1.3 Summary discussion for RQ3 A

Pertaining to research question 3 A (What is the trend of Zambian primary school teachers' conceptual and operational understanding of SPS?), the research uncovered a general tendency.

The respondents' conceptual understanding of SPS was relatively low as results obtained displayed seven skills which depict a 58% of the 12 SPS spread relatively more in the low mean score range. While in the case of their operational understanding of these skills, eight skills (67%) of the 12 SPS spread relatively more in the high mean score range. Teachers' performance depicted a good operational understanding of SPS but insufficient conceptual understanding underlying the skills.

Most respondents could apply the skills in hypothetical situations incomparable to using the skills conceptually, as stated in some previous study findings such as (Emereole, 2009). The mean score results for respondents' operational was above average score. The respondents' conceptual understanding of the SPS was insufficient. These findings show a disparity between the respondents' conceptual understanding and the operational understanding of SPS as supported by some previous study e,g. Shahali et al.,(2017). An implication is that teachers' SPS acquisition operational wise is more likely to be higher than teachers' conceptual mastery of SPS.

8.1.4 Summary discussion for RQ3 B

Shown in Table 35 are the summary discussion on the results for research question 3 B (What are the patterns of Zambian primary school teachers' conceptual and operational understanding of SPS across five Independent Variables).

Table 35. Summarized Discussion for RQ3 B

		Pattern	
No.	**Variable Name**	Conceptual Understanding	Operational Understanding
1	Gender	Non-Repeated Occurrence	Repeated Occurrence
2	Teaching Experience	Non-Repeated Occurrence	Non-Repeated Occurrence
3	Teaching Qualification	Repeated Occurrence	Non-repeated Occurrence
4	Teaching Grade Level	Unreported Occurrence	Unreported Occurrence
5	Teacher SPS Facilitation	Repeated Occurrence	Repeated Occurrence

The participants' conceptual understanding of SPS shows no significant difference across gender. Results of the study are inconsistent with results of similar studies previously conducted stating that teachers' conceptual understanding of SPS differs across gender groups, e.g., (Aydoğdu, 2014).

Results under the teaching qualification variable regarding their conceptual understanding reflected that teachers with lower teaching qualifications outperformed those with a higher education qualification in the SPS test. This rare finding was investigated by conducting interviews with some teachers according to the teaching qualification levels under this study. Reasons for teachers with certificate qualifications outperforming the diploma/degree qualification in the SPS test included disparities in training time, subject content coverage, teachers' motives for obtaining higher teaching qualifications had an impediment of their SPS understanding levels. Meanwhile, their operational understanding of SPS across gender was significant, depicting a repeated occurrence of findings from previous studies. The teaching experience variable displays a pattern inconsistent with earlier studies for both conceptual and operational understanding of the SPS of the participants. As for the teaching grade-level variable, a nonoccurrence pattern is realized in teachers' conceptual and operational understanding of SPS. This nonoccurrence finding can be attributed to previous studies that focused on teaching grade-level variables with preservice teachers and pupils but not Inservice teachers, e.g., (Farsakoğlu, 2012) and (Özgelen, 2012). Lastly, participants' conceptual and operational understanding across the teacher SPS facilitation level variable reflects a series of records that repeats identifiably. An insignificant association between primary school teachers' conceptual and operational understanding of SPS concerning facilitation levels of SPS was revealed. Bivariate Pearson Correlation results show a negative association ($r = -0.292$) between teachers' conceptual understanding and their SPS facilitation level, while their operational understanding of SPS stood statistically at zero association ($r = 0.00$, $p \geq 0.05$). Results obtained supported by some studies that science teachers involved in facilitating SPS learning still had some difficulties planning, executing, and enabling SPS student assessment, e.g. (Permanasari, 2013).

8.2 Conclusion

In conclusion, this study indicates that the Zambian primary school teachers involved (regardless of their gender, teaching experience, teaching qualification, teaching grade level) have an insufficient conceptual understanding of SPS. On the other hand, the respondents' operational understanding of these skills was relatively moderate. Even as recounted in preceding investigation studies, school teachers with an inadequate conceptual understanding of SPS are unskilled in using effective teaching and related learning strategies in their classrooms (Mushani, 2021a). If teachers' conceptual understanding of SPS is insufficient, they will focus on the operational aspect during classroom activities. The practical implementation of science at the primary school level will also produce learners who adhere to directions and attain soaring results devoid of comprehension of the SPS they apply in their daily science routines. SPS are of noteworthy in science education from way back until now. Several studies have outlined that SPS development in science education remains a need for developed and developing countries. SPS still are a basis for developing other skills individuals should possess for daily use.

Teachers' understanding of the SPS has a significant impact on science education, especially in the era of 21st-century learning. Science teachers whose understanding of SPS is higher are good at facilitating learners' acquisition, development, and application of these skills during classroom activities. The high-level teachers' understanding of these skills leads to effective, efficient, and quality implementation of science education at any level.

None of the studies on teachers' understanding of SPS reviewed is from Africa. Besides, various examined research works on the importance of SPS are for exploration work carried out in technologically advanced nations. This creates an obligation for more research work to be carried out in future. And would lead to the discovery and identifying various solutions to challenges experienced in promoting practical science teaching and learning, especially in emerging nations.

8.3 Recommendations

This study recommends the following:

1. The teachers should conduct self-evaluation to improve their ability in understanding more about Science Process Skills (conceptual and operational wise) in teaching and learning.
2. Teacher educators should accord SPS education a critical consideration during teacher preparations/training.
3. Curriculum and Examination Bodies should ensure the unbiased incorporation of SPS education in all education documents.
4. Other researchers help conduct further research on how the existing trend and patterns in teachers' conceptual and operational understanding of SPS could be improved positively.

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APPENDICES

1. Survey Approval Request – School Level

58

An Investigation of Primary School Teachers' Conceptual and Operational Understanding of Science Process Skills in Zambia

Science Process Skills Survey

Dear Respondent,

This study, by the Directorate of National Science Centre, focuses 'Investigating Primary School Teachers' Understanding of Science Process Skills: A Case Study of Zambia". The primary purpose of this study is to analyze_ teachers' conceptual and operational understanding of Science Process Skills and evaluate their conceptual and operational understanding of these skills concerning quality science skills education at the Primary School Level in this 21st Century Era.

As an Educator, your responses to questions in this questionnaire will be of great use to make necessary recommendations in line with skills development through quality science education in our country.

This study, by all means, doesn't intend to evaluate you or your individual information. Preferably, it will report only the overall results, and therefore, your responses will be kept confidential and anonymous. Thus your clear and honest answers will be highly appreciated.

V./e are grateful for the time you will spend responding to these questions; in case of any inquiries, kindly feel free to contact us should the need arise.

REPUBLIC OF ZAMBIA
MINISTRY OF GENERAL EDUCATION
21 APR 2021
HEADTEACHER'S OFFICE
LITETA PRIMARY SCHOOL
P.O. BOX 48, CHIBOMBO

Headteacher

2. 1st Survey Instrument - Test on Primary School Teachers' Conceptual Understanding of SPS.

Research Instrument: ***Science Process Skills Test (SPST)*** *– developed through adapting some questions from Burak et al. (2007) and Molefe et al. (2016).*

Organization of the Survey: The Survey has three (3) sections/parts, and each section/part has instructions. Kindly read the instructions before responding.

Part A: Demographic Information - Kindly supply the following information regarding your experiences and background by checking in the appropriate box.

1. Gender
   - ❑ Male
   - ❑ Female
2. Teaching Experience (years)
   - ❑ 1-5
   - ❑ 6-10
   - ❑ 11-15
   - ❑ 16-20
   - ❑ 21-25
   - ❑ 26 and above
3. Teaching Grade Level
   - ❑ Lower Primary Level
   - ❑ Upper Primary Level
   - ❑ Both levels
4. Teaching Qualification/s
   - o Certificate in Education
   - o Diploma in Education
   - o Degree in Education
   - o Master’s Degree in Education
   - o Post Graduate Degree in Education

5. How often do you facilitate learners' acquisition and development of Science Process Skills during the science teaching and learning process? ***(Circle your choice, please.)***

   A. Very often
   B. Quite often
   C. Not often
   D. Not engaged at all

Part B: Conceptual Understanding of Science Process Skills (Multiple Choice Questions)

6. What Science Process Skill are pupils using if they smell smoke from a burning bush near their classroom?

A. Defining operationally
B. Communication
C. Formulating models
D. Observation

7. Which Science Process Skill involves guessing what might happen in the future?

A. Inferring
B. Hypothesizing
C. Predicting
D. Experimenting

8. Pupils in grade 3 were given a lever balance (like the one shown below), a lump of plasticine and lots of equal-sized blocks. They were then asked to work out how many blocks weigh the same as the lump of plasticine. Which Science Process Skills are the pupils acquiring and developing while carrying out the activity?

A. Prediction
B. Non-Standard Measuring
C. Hypothesis
D. Standard Measuring

9. What name is given to a type of Science Process Skill when a set of objects is divided into two subsets?

A. Binary classification
B. Serial ordering
C. Multistage classification
D. Uncertain

10. What effect does **<u>a decrease in the temperature of a room</u>** have on the battery's lifespan? Which variable is the underlined bold sentence representing?

A. Dependent variable
B. Independent variable
C. Measuring variable
D. Inferring variable

11. What Science Process Skill will you be using if you teach pupils how to play a game?

A. Classifying
B. Measuring
C. Communicating
D. Hypothesizing

12. In the Primary School Science Lab corner, what Science Process Skill will your pupils use to read the graphs about temperature?

A. Classification
B. Analyzing Data
C. Prediction
D. Formulating Models

13. If it is cold outside, pupils will wear blue cardigans. This is an example of a(n):

A. Hypothesis
B. Inference
C. Prediction
D. Observation

14. What Science Process Skill involves the process of considering the evidence and drawing a conclusion by assessing the data provided?

A. Interpreting
B. Hypothesis
C. Analyzing Data
D. Classifying

15. Which Science Process Skill is developed by pupils when representing objectives or ideas during science learning time?

A. Experimenting
B. Observations
C. Defining Operationally
D. Formulating Models

16. Sometimes, teachers engage pupils in creating definitions based on initial observations during science lessons activities. What Science Process Skills are teachers helping their pupils acquire and develop during such activities?

A. Classification
B. Experimenting
C. Defining Operationally
D. Identifying and Controlling Variables

17. Which Science Process Skill uses a test under controlled conditions?

A. Making Models
B. Experimenting
C. Making Models
D. Hypothesis

18. Of the following, which is a qualitative observation?

A. It has a mass of 10.1g
B. I like the blue colour
C. It is 5cm long
D. It is blue

20. When a pupil shares her findings with other pupils in class, then she is …………………….

A. Analyzing Data
B. Communicating results
C. Experimenting
D. Making Hypothesis

21. What do we call changes that occur in an experiment and are directly caused by the experimenter (you)?

A. Independent Variables
B. Dependent Variables
C. Hypothesized Variables
D. Predicted Variables

22. Does heating a cup of water allow it to dissolve more sugar? There are two variables in this question statement: 1. Water temperature 2. Amount of dissolved sugar. What Science Process Skill would pupils acquire and develop as they carry out this experiment concerning variables?

A. Dependent Variable
B. Experimenting
C. Formulating Hypothesis
D. Identifying and controlling Variables

Part C: Operational Understanding of SPS
(Kindly respond to the following based on each question item's instructions).

23. The table below lists statements referring to how Science Process Skills are acquired and developed by pupils through teachers' facilitation during science lessons.

Task (1): As an expert science teacher, indicate by ticking alongside each statement whether or not you have facilitated pupils' acquisition and development of the skill/s referred to in each facilitation statement. ***(Tick in the appropriate cell concerning your response).***

Science Process Skills Facilitation Related Statement	***Never***	***Sometimes***	***Often***	***Always***
1. I encourage pupils to use any means to communicate learned information, i.e., drawing maps, charts, symbols, graphs, and diagrams to communicate the data.				
2. I organize classroom activities in which pupils classify the observed scientific things.				
3. I organize activities where my pupils compare objects using standardized units of measure and suitable measuring instruments.				

4. I encourage my pupils to predict future science-related events based on their observations.				
5. I encourage pupils to use various forms of data to determine the correctness of the scientific theory.				
6. I encourage pupils to identify variables that affect science experiments, e.g., how air temperature, air, water, and fertilizer influence the growth of a plant.				
7. I devise exercises in which my pupils construct tables of data/graphs to explain some test results.				
8. I devise activities where my pupils conduct investigations to test a scientific hypothesis.				
9. I give exercises in which my pupils define living/non-living things by using observable characteristics of the features.				
10. I give my pupils hypotheses and request them to design investigations to test the shared assumptions.				
11. I give my pupils scientific problems that encourage them to construct hypotheses.				
12. I give my pupils many opportunities to identify critical scientific situations using their senses.				

3. Interview Schedule on 1st Survey Unique Finding on Participant's Conceptual Understanding across Teacher Qualification Variable

Focus Area	Questions and Probes
1. Demographic Information	What are your names? How long have you been in the teaching profession? Which grade level(s) have you been teaching? What is your teaching qualification?
2. Conceptual Understanding of Science Process Skills (SPS)	What do you understand by SPS? How do you rate your understanding level of SPS?
3. Perceptions/Perspectives of Teaching Qualification and Teachers' Understanding of SPS.	Does teaching qualification bear any influence on a teacher's understanding of SPS? How would you explain a case where certificate holders outperform degree or diploma holders in an SPS test?

4. 2nd Survey Instrument – Test on Primary School Teachers' Operational Understanding of SPS

Organization of the Survey:

The Survey has two (2) sections/parts; each section/part has instructions. Kindly read the instructions before responding.

Part A: Demographic Information - Kindly supply the following information by ticking in ☑ the appropriate spaces ().

NO	ITEM	INFORMATION
1.	Gender	1. ( ) Male 2. ( ) Female
2.	Teaching Qualification	1. ( ) Certificate in Education 2. ( ) Diploma in Education 3. ( ) Degree in Education 4. ( ) Master's Degree & Post graduate degree in Education
3..	Teaching Experience (years)	1. ( ) 1- 5 2. ( ) 6- 10 3. ( ) 11- 15 4. ( ) 16 - 20 5. ( ) 21 – 26 6. ( ) 26 Above
4.	Teaching Grade Level	1. ( ) Lower primary level 2. ( ) Upper primary level 3. ( ) Both levels

Part B: Science Process Skills Focus Questions

This section comprises two (2) sub-sections, B1 & B2, presented below. Kindly respond to each based on the instructions given alongside each sub-section heading.

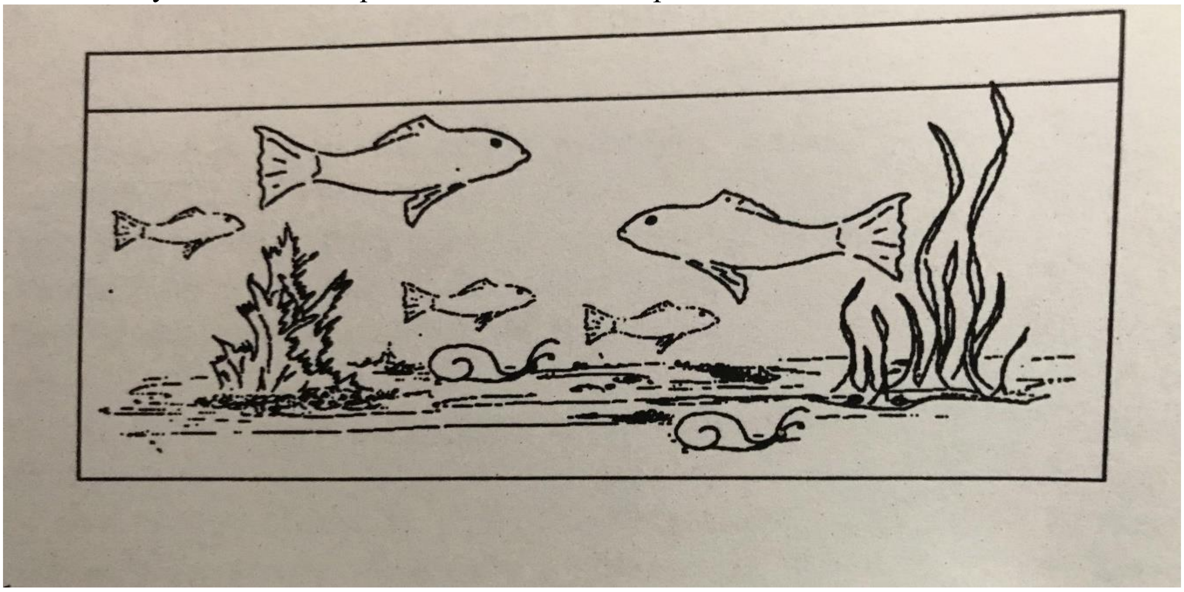
Part B1: - Frequency questions (Teachers' Perception/Perspective on SPS Facilitation)

8. Tabulated below are five (5) statements on Science Process Skills regarding science teaching and learning. Kindly use the symbols (✓) for YES and (x) for NO alongside each statement in the appropriate box.

STATEMENT on SPS	YES	NO
A. My understanding of how to facilitate student acquisition of all the Science Process Skills is of high level.		
B. I prepare and plan science lessons to facilitate pupils' acquisition and development of Science Process Skills.		
C. I include all the Science Process Skills in each science lesson plan before teaching my pupils.		
D. I always ensure that pupils use Science Process Skills when engaged in science practical activities within and outside the classroom.		
E. I prepare both formative and summative assessment tasks for checking the development of Science Process Skills for my pupils.		

Part B2: - Multiple Choice Questions (Operational Understanding of SPS)
This section comprises 12 questions, one for each Science Process Skill. Kindly provide the appropriate response/s to all the questions.

9. What do you see in the aquarium tank shown in picture A below?

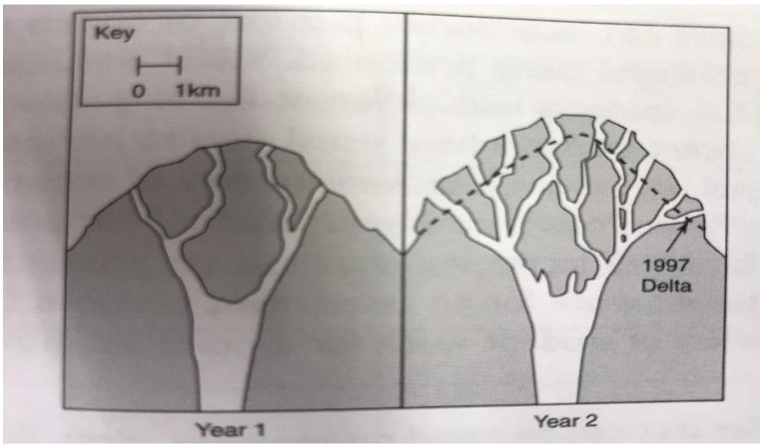


Picture A

Select the appropriate answer from the following options:

A. Some fish are bigger than others.
B. The small fish are babies of the big fish.
C. Snails and fish don't like each other.
D. The plants will not have enough air.

10. Picture B below shows the development of a delta for two years. According to this information, how far did the delta reach into the ocean after 1997?



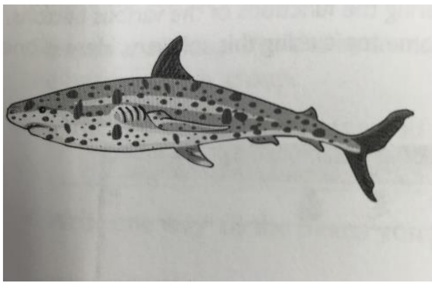
Picture B

A. 0.1 km
B. 0.5 km
C. 1 km
D. 1.5 km

11. You want to perform a standard measurement of the volume of a rock. The best way to do this is with

A. a ruler, water, and a balance
B. a beaker and water
C. a beaker, a hot plate and water
D. a beaker, a graduated cylinder and water.

12. Study the information provided below in picture C and Classification Key.



Picture C

Classification Key

1a. Body kite-like in shape……………………….Ray
1b. Body not kite-like in shape ………………Go to 2

2a. Nose saw-like in shape ………………….Swordfish
2b. Nose not saw-like in shape………………Go to 3

3a. Head extended on both sides ……Hammerhead Shark
3b. Head not extended on both sides …….Go to 4

4a. Body has spots ………………………….Leopard shark
4b. Body does not have spots…………….Nurse shark

Using picture C and the classification key above, what is this animal?

A. Swordfish
B. Hammerhead shark
C. Leopard shark
D. Nurse shark

13. A grade five teacher prepared this summative question to assess pupils' usage of a particular Science Process Skill at the end of a science lesson. The chart below shows how long it took seed to sprout at three different temperatures.

Temperature	Days Needed to Sprout
60° C	15
65° C	13
70° C	11

Based on the chart, how long will it take for the same kind to sprout at 75° C?

A. 11 days
B. More than 11 days
C. Less than 11 days
D. None of the above

14. Look at picture B below. What will probably happen if the plant is turned around to face the opposite direction?

Picture B

A. It will stand up straight.
B. Its leaves will fall off.
C. It will bend back toward the sunlight
D. Its leaves will turn yellow.

15. Examine the data table below and select the most appropriate hypothesis regarding dissolving time and water temperature.

	Average dissolving time (in seconds)			
Substance	Water 20ºC	Water 40ºC	Water 50ºC	Water 60ºC
20 grams of Sugar	80	40	20	5
20 grams of salt	60	30	16	3

A. There is no difference in the dissolving time of the substances due to water temperature.
B. The lower the water temperature, the shorter the dissolving time of the substances.
C. The higher the temperature of the water, the shorter the dissolving time of the substances.
D. It is impossible to make a hypothesis from the information given in the chart.

16. The following data is taken from an experiment:

Temperature (average)	Seed Weight (gram)	Water Consumed (ml/day)	Exposure to Light (min./day)	Plant Height (cm/20 days)
20ºC	2.2	10	20	20.2
50ºC	2.3	10	20	20.3
30ºC	2.3	10	20	20.2
25ºC	2.1	10	20	20.3
25ºC	2.3	10	30	21.9
25ºC	2.3	10	40	22.8
20ºC	2.2	10	30	21.8
20ºC	2.1	20	30	21.9
20ºC	2.2	30	30	22.0

Based on the data above, what factor do you think influences the plant growth's speed most?

A. The temperature where the plant is grown.
B. The seed weight.
C. The amount of water consumed every day.
D. The length of the period the plant is exposed to the light.

17. Which one best describes the process of creating a mental or pictorial representation to explain an idea or event?

A. The pupils created facial images to explain how they feel when they see a snake.
B. Pupils were copying notes from the blackboard.
C. The pupils were drawing a plant flower grown in the school garden.
D. None of the above.

18. A grade 7 pupil wants to test to see if the colour of cloth influences the amount of heat absorbed. She plans an experiment using two cloth colours to wrap two different glasses containing the same amount of water. One glass is wrapped with green cloth, and the other is yellow. She puts them under the sun's rays and a thermometer to observe the temperature in each glass. What things can you suggest to improve her testing?

A. To add to the number of glasses to be covered with the cloth.
B. To reduce the amount of water in each glass.
C. To prepare more containers, each is covered with a different cloth colour.
D. To double the size of the cloth used to cover the glass.

19. Which one of the following statements is written as an operational definition?

A. Since the oil density is lower than water, the oil will float on the water's surface when mixed with oil.
B. The speed of a supersonic jet is similar to the speed of sound waves.
C. When you drive your car at a speed of 30 miles per hour, you have to push the brake pedal 300 feet before the line or point you plan to stop.
D. The speed of a car will decrease when it has to turn right or left.

20. Mulenga and Jelita want to know if there is any difference between the mileage expected from bicycle tires from two different manufacturers. Mulenga will put one brand on his bike, and Jelita will put the other brand on her bicycle. Which of the following variables would be most significant to control in this experiment?

A. The time of day the test is made.
B. The number of miles travelled by each type of tire.
C. The physical condition of the cyclist.
D. The weather conditions.
E. The weight of the bicycle used.