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A Review of Research Findings and Trends of Articles on Science Process Skills in Africa from 2002 to 2021

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Abstract

The developmental period of the African science curriculum has principally viewed Science Process Skills (SPS) as a major outcome. However, the scarcity of review regarding the African studies in SPS points to a crucial gap in the related literature. This warrants the need to review research articles on SPS thereby identifying common findings and distinguishable trends. Therefore, this review aimed to analyze and evaluate research studies conducted on science process skills in the context of African countries. The method carried out in this research was a systematic literature review. It involved analyzing and synthesizing studies that focused on science process skills in the African science education from 2002 to 2021. The researchers obtained 106 articles in the initial searching activity. Then, they screened out the abstract of these articles to determine their relevance. From this screening process, 34 SPS studies in different African countries published from 2002 to 2021 were synthesized and analyzed. The review of research trends on SPS-related issues conducted in African countries focused on the following points: contributor African countries, main SPS-related issues discovered by the studies, and the methodologies used by the researchers. Based on the result of this review, the top three SPS-related issues identified were; determining variables affecting SPS (23.52%), developing science curriculum via SPS (17.64%), and developing students' and teachers' SPS (17.64%). The results also revealed that most articles were contributed from Nigeria (44.11%) and the most frequently used research

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design and methods were quantitative research design (58.82%) by quasi-experiment, survey, and ex-post-facto methods. The most frequently used data collection tools were achievement tests (45.71%) and document analysis (31.42%), and the most frequently used samples were the students at high schools (65.71%). Since science curriculum plays a vital role in improving students' SPS, the results of studies under investigation suggested that curriculum developers may increase the number of science activities when developing science curriculums.

***Keywords**: African continent, science education, science process skills, students, teachers*

Introduction

1.1. Background of the Study

Science and technology have seen a rapid progress in the world in the 21st century. Because of the effects of testing new ideas in the world either by research institutions, or others, knowledge has been increasing rapidly. However, students across many disciplines could not get all the required information [1]. Hence, it is not just necessary to show students all the knowledge but to teach them those skills, associated with acquiring this knowledge. After independence, the educational systems of some African countries have changed. Currently, African countries have been making relentless efforts to improve the quality of science education by putting science education at the center of the broader educational goals for the society. In those countries, the education systems have changed from rote learning to inquiry activity to problem-solving skills; from teacher-centered approaches to student/discipline-centered approaches; more subject integration, less dependent on traditional textbooks, and more concern for intellectual skills. For instance, in Uganda, these changes have been attributed to produce students who seek jobs through inventing jobs on their own. This system has also emphasized education for self-reliance in Tanzania. Other African countries have also highlighted the pride of hard work, pastoral revolution and pastoral incorporation [2].

Science education is supposed to bring about economic development [3]. Awareness of science education plays a role in preparing learners for their future roles in the society as responsible citizens. Similar to other communities worldwide, the African people have recognized that creative and innovative learning skills are essential for the emerging work environment in the 21stcentury.

Among the 21st century skills, science process skills (Here after SPS) are the most important skills necessary to come up with solution of any problem, identify the representation of the problem, and thus the application of systematic process skill is needed [4].

Science process skills (SPS) have different meanings in science education. For example, according to Bati *et al*. [5], science process skills are competencies that enable students to acquire knowledge and understand the knowledge obtained. Science process skills are grouped into two groups: basic and integrated SPS. According to Padilla [6], the basic SPS include observing, inferring, communicating, classifying, predicting, and measuring. On the other hand, integrated SPS are related to controlling variables, defining operationally, interpreting data, experimenting, formulating models, and formulating hypotheses. The teaching of SPS has become a significant component in the science curriculum at all levels in many countries. It has also become one of the new

approaches in teaching science more effectively and meaningfully. For example, from the review of the science in 2002, teaching SPS for both primary and secondary levels was explicitly observed in Malaysia. The objectives of SPS and inquiry skills were developed to primary and secondary school science syllabuses. It is imperative that acquisition of science process skills can influence the development of mental processes such as higher-order critical thinking and decision making. Individuals need to develop the analysis of higher-order thinking skills that enable them think creatively and transfer this capability to the other disciplines [7]. Therefore, it is necessary to teach SPS for students from the earliest stages of primary school up to the highest level in their formal education. According to Mushani [8], SPS in science education have showed more research studies in the developed countries than in the developing ones. In a similar vein, the findings of this review have also indicated uneven inclusion of SPS in the science curriculum documents and curriculum implementation at all science education levels although as Harlen [9] posits, science process skills (SPS) serve as a driving factor for scientific inquiry.

In the teaching and learning of scientific content knowledge, a close relationship between SPS and science applications plays a cornerstone role [10, 11]. The principal aim of science education is to allow students to grasp SPS [10]. Therefore, equipping students with science process skills are needed [12]. The integration of process skills into the learning environment has been emphasized in the curricular development both in the developed and developing countries [13]. Curriculum outcomes via SPS are expected to facilitate science learning, engage students to actively participate in their learning continuum as they can underpin analytical thinking, construct knowledge through problem-solving [14]. Therefore, the developmental period of the African science curriculum has principally viewed SPS as a significant outcome [15]. Hence, the questions like, what should be done to develop science process skills? What are the most effective strategies in improving SPS?; What is the roles of the teacher and students in developing SPS?; What are the teacher's and student's insights of SPS?, have recently attracted the attention of most science educators.

1.2. Statement of the Problem

In the reviewed literature, some reviews dealt with various SPS-related issues in developed countries. Some others were SPS towards hard of hearing and deaf students by Ediyanto *et al*. [16], science process skills in both developed and developing countries, research trends focused on Science curriculum, 21st century learning, and teacher education [8]. Additional review was also carried out on the issue of improving science teachers' conception of the nature of science by Fouad & Norman [17]. Data from the African Science, Technology, and Innovation Indicators Initiative (ASTII) and

the UNESCO Bureau of statistics showed that fewer researchers who conducted science education research were in Africa from 2011 to 2013, and the lack of a review regarding the SPS study in African countries pointed to a crucial gap in the related literature, which warrant the need for the analysis of African studies in SPS and thereby identifying their common and distinguishable trends. In light of all these concepts and empirical evidence, this study aimed to evaluate the African studies in SPS from 2002 to 2021 to address the following research questions.

1. Which African countries were involved in SPS studies conducted from 2002 to 2021?
2. What were the SPS-related issues focused by the African SPS studies from 2002 to 2021?
3. What were the most frequently used research methodologies by African SPS studies from 2002 to 2021?

1.3. Objectives

This review mainly intended to investigate research trends and findings of SPS articles conducted in African countries regarding science process skills from 2002 to 2021.

The present study included the following specific objectives based on the above basic questions;

1. To identify the African countries that participated in SPS studies conducted from 2002 to 2021.
2. To explore the main SPS related issues identified in African studies conducted from 2002 to 2021.
3. To assess the research methodologies used to study SPS in Africa from 2002 to 2021.

1.4. Significance of the study

According to Çalık & Sözbilir [18], the action of evaluating and synthesizing studies shows not only research trends but also emphasis of research papers. The present review is significant for decision-makers, practitioners, and curriculum developers to conceptualize, plan and integrate SPS into the curriculum. It can be used as a baseline data for researchers thereby avoiding recapping similar SPS studies and overcoming their uncertainties. In addition, it is also significant for beginner researchers and teachers interested in implementing findings of science curriculum-based SPS study in the teaching-learning activities.

2. RESEARCH METHODOLOGY

This study intended to analyze a review of African studies in SPS. The full papers of journal articles published from 2002-2021 were available on different databases with the

English language and only science process skills rather than other skills. This setting was selected because teaching and learning of SPS have been prevalent in research since early 2000 in Africa. However, it is also important to note that SPS teaching and learning activities started in the early 1980 in developed countries. These activities were predominantly researched in Africa since 2002.

2.1. Database Search and Selection Criteria

The researchers ran a database search from September 2021 to December 2021. To answer the research questions, the researchers searched related articles with keywords such as 'process skills, science process skills, science education, and Africa in the following databases: Academic Search Complete, Education Resources Information Center (ERIC), Taylor and Francis Journals, and Google Scholar. As a result, 106 total articles were obtained from the initial searching. The researchers screened out abstracts of these articles to determine their significance in line with the considered inclusion criteria (Table 1). This screening led us to further read 43 studies, whereas 63 were dropped from the initial list, for some of them focused on other skills such as problem-solving skills, higher order thinking skills, or because their full papers could not be accessed. After further checking, their duplication and continent, where nine articles were omitted due to duplication (3) and for, they were not from African countries (6). Finally, 34 peer-reviewed articles were included for the present review (Table 1 and Figure 1).

Table 1. Inclusion and exclusion criteria for science process skill studies

Criteria	Inclusion	Exclusion
SPS studies wrote in English	√	
SPS studies published from 2002-2021	√	
Studies focused on science process skills	√	
SPS studies with full paper available	√	
SPS studies conducted in African countries	√	
SPS studies without full paper available		X
Unpublished SPS papers		X
Studies on other skills like higher order thinking skills and problem solving skills		X
SPS studies wrote in another language		X
SPS studies published before 2002		X

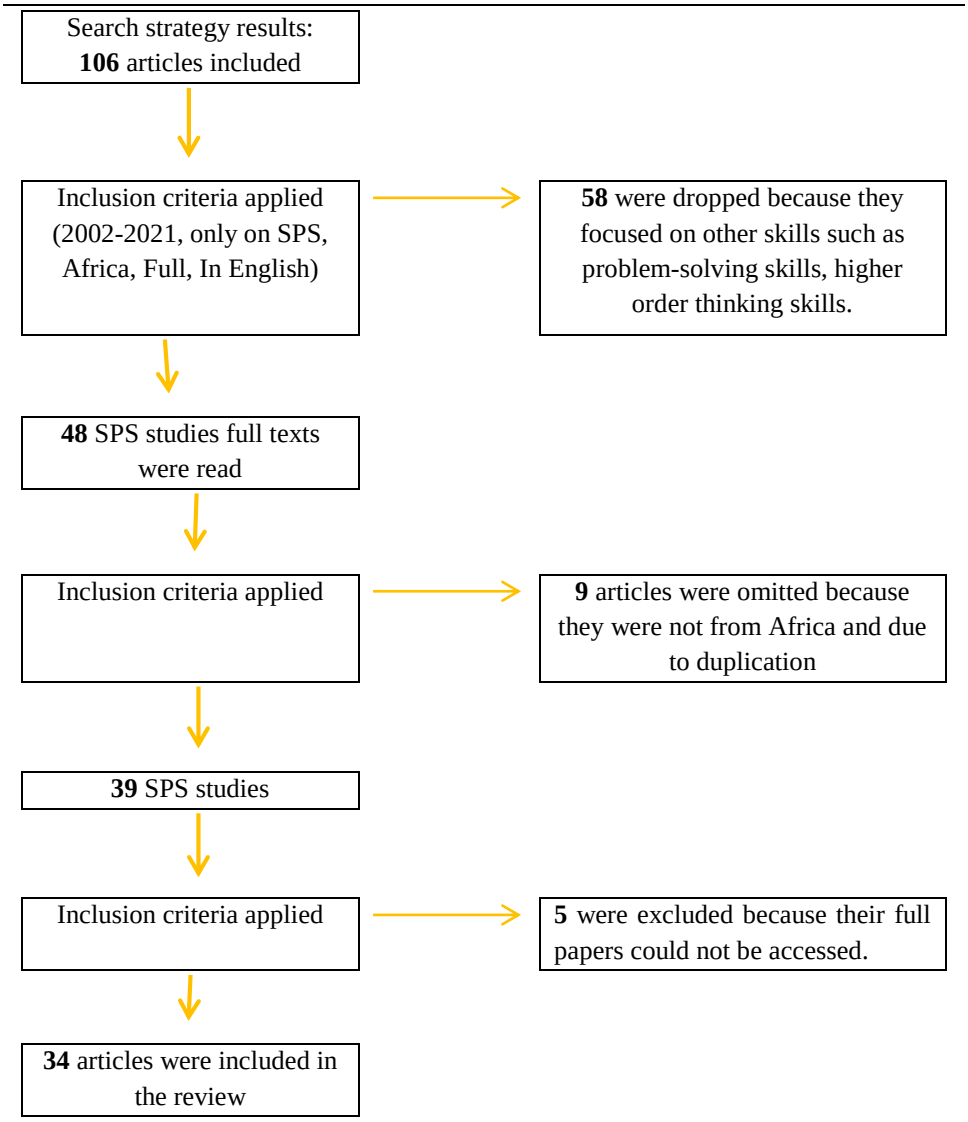

Figure 1. Flow charts of articles selected for the review of SPS studies in Africa

2.2. Data Analysis Method

The data obtained from the collected journal articles were exported to an Excel spreadsheet and analyzed using Excel statistical software program. The data were compiled and tabulated with descriptive statistics to show the number and percentage of

aims, research methods, samples, and data collection tools of researchers using tables and figures.

3. RESULTS AND DISCUSSIONS

This section presents the literature review findings of African research trends on SPS. The first section provides information about the major African countries that contributed to SPS studies from 2002 to 2021. The next part discusses the results of the SPS-related issues reported by African SPS studies. The final section shows the most frequently used methodologies the researchers used in their investigations.

3.1. Review results for the participation of African countries on Science Process Skill Studies from 2002 to 2021

According to *Ogunniyi* (1986), starting from early 1960, the objectives of science education in all independent African states included many things related to SPS. The SPS-related issues included in their curriculum were the following: (A) The development of the essence inquiry; (B) the teaching-learning activity of problem-solving using scientific process skills (like observation, measurement, formulating or testing a hypothesis, experimentation, and other skills) and (C) the development of manipulative skills and scientific attitudes. Though this is the goal of the continent's curriculum, the involvement of researchers to study this condition has been low due to many reasons. For example, the budget allocation from the governments of many developing countries to support scientific research was limited. Therefore, the number of African continent research in SPS studies was less when compared to its high demand in the 21st century learning. The present review finding was one piece of evidence for the existence of this gap. Even though there are more than 50 countries on the African continent, the number of countries that participated in SPS studies was lower than expected, nearly seven countries from the 54 African countries. Table 2 displays the name of authors with the number of their respective countries. As Table 1 shows, out of the 34 SPS Africans' studies, most of the studies i.e., 15 (44.11%) were from Nigeria, 6 (17.64 %) from South Africa, 5 (14.70%) studies from Kenya, 1 (2.94%) from Ghana, 2 (5.88%) from Zambia, 2 (5.88%) from Tanzania, 2 (5.88%), and out of all the analyzed studies in Africa, 1 (2.94%) were from Ethiopia.

Table 2. The distribution of SPS studies in African countries across years from 2002-2021

Country	Number of articles	%	Authors
Nigeria	15	44.11%	[19-35]
South Africa	6	17.64 %	[36-39]

Kenya	5	14.70%	[34, 40-42]
Ghana	1	2.94%	[43]
Tanzania	2	5.88%	[44, 45]
Zambia	2	5.88%	[46, 47]
Not specific	2	5.88%	[8, 48]
Ethiopia	1	2.94%	[49]
Total	34	100%	

Figure 2 below illustrates that the SPS researchers in some countries like Nigeria, Kenya and South Africa were still devoted to conducting SPS studies across the years (shows a slowly increasing trend). On the other hand, researchers in other African countries such as Ghana, Zambia, and Ethiopia started and stopped (gradually decreasing trend). So, these participant countries did not show any significant change over the years. However, researchers from most countries of the African continent have not participated in SPS studies.

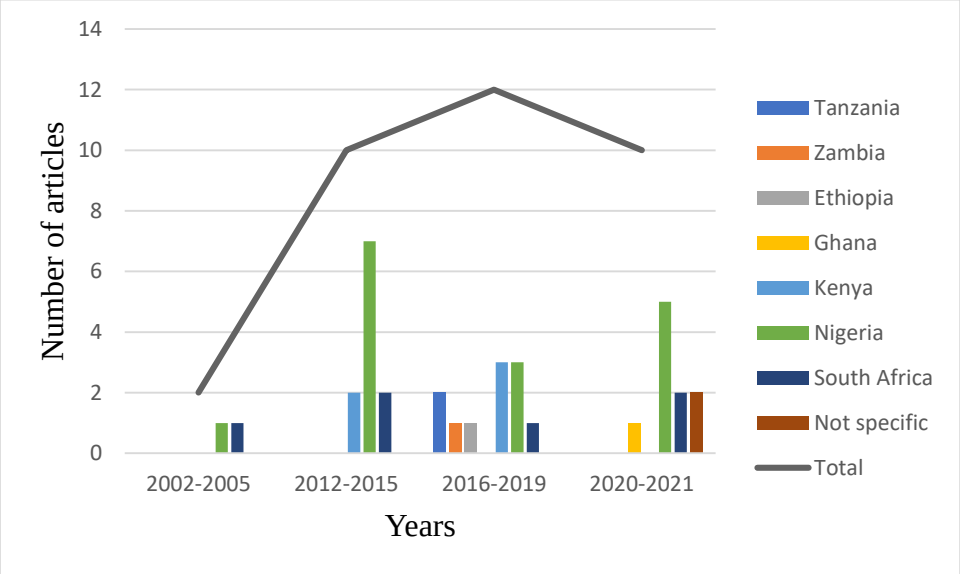

Figure 2. Trends in doing SPS studies in African countries across years (2002-2021)

Generally, as Figure 2 shows, the participation of African countries in SPS studies showed a slightly increasing trend starting from 2012, and countries' contributions reached their peak in 2016 and 2019.

3.2. Findings on the Science Process Skills-related issues reported by African SPS Studies from 2002 to 2021

There were six reviewed findings under this section. These are developing science curriculum via SPS; developing students' and teachers' views of SPS; determining variables affecting SPS; measurement instruments for SPS; the relation between SPS and other skills (i.e., academic achievement or scientific creativity), and effect(s) of SPS-based science teaching on students' attitudes towards science, creativity skill and academic achievement. Table 2 shows the number of African SPS articles, authors, and the SPS issues reported.

1. The first SPS-related issue studied by most of the researchers was determining variables affecting SPS where eight (23.52%) studies investigated this issue. The reviewed articles showed the presence of different factors that could influence SPS. Teaching methods such as guided inquiry with analogy instructional strategy [21] and reflective - reciprocal teaching [22], gender [23], and Practical work [43] were the main factors that could affect SPS in African science education.
2. The second main SPS-related studies focused on developing students' and teachers' SPS. In the present review, 6 (17.64%) of the studies assessed the level of teachers and students' possession of SPS and discussed ideas that were related to SPS development. Understanding the importance of the development of SPS for both teachers and students was studied earlier with authors from other countries, for example, by Teo Yew Mei (2007), Keli, Jodi, and Jennifer (2009) (cited in Sukarno, Permanasari & Hamidah (2013)). African researchers also tried to investigate, (e.g., Rambuda & Fraser [50], Johannes Ambross *et al*. [33], Molefe *et al*. [37], and others in (Table 3), revealed that most pre-service and preschool teachers were either aware of or skilled in increasing SPS. So, in-class does not specifically ensure that students attain these skills. The finding may be valuable in shaping and revising school practice and curriculum. Because in science education, it is necessary to develop SPS to ensure students' mastery of the concepts they taught.
3. The other issue was developing a science curriculum via SPS. SPS has recently become one of the objectives of science education to bring students into scientific thinking skills. Due to this, nowadays, many countries have emphasized these issues in their curriculum. According to Cepni *et al*. (cited in Yumusak, 2016), science process skills are the principal skills used to monitor research means and methods that qualify the easy learning and persistence of science; and deliver students to be accountable and active in their learning. Six (17.64%) of the reviewed African SPS articles that investigated the issue of developing African curriculum via SPS included Ango [19]; Opateye [20]; Billy Siachibila & Asiana Banda [46], and others indicating that the study of SPS enabled teachers to make the science appealing and interesting for students through inquiry-based learning.

4. Based on the findings of Aydin-Ceran and Ates (2020), "There is a need to discuss how SPS should measure? Using open-ended or performance-based tests by moving away from traditional methods in measuring scientific process skills will produce more valid results". The African SPS studies that revealed valid and reliable instruments are needed to measure SPS, e.g., as Leny *et al*. (2019); emphasized that measurement is a prerequisite for posing the next steps of SPS (i.e., teaching intervention). However, in some African countries, the presence of these appropriate SPS measurements tools was not found correctly. For example, as Ouko *et al*. [42] revealed, teachers in Kenya responded that the KCSE biology practical assessment approach did not give opportunities for the candidates to carry out experiments to a satisfactory extent. The teachers showed their disagreement on the idea that the KCSE biology practice test measures the SPS of students. Table 3 displays 3 (8.82%) of the reviewed articles that discussed this issue.
5. The other issue studied in the African SPS studies was determining teachers' and students' views of SPS. Five (14.70%) of the reviewed articles of Rambuda & Fraser [50]; Johannes Ambross *et al*. [33], Molefe *et al*. [37]; Ouko *et al.* [42]; Ogegbo & Ramnarain [38]; Molefe & Aubin [39] examined this point. Regarding this, some teachers and students perceived that SPS had a positive effect on science education. For example, Molefe *et al*. [37] found out that student teachers viewed most SPS and related skills including problem-solving or critical thinking as significant for acquisition in teacher education programs and personal acquisition.
6. Determining the effect(s) of SPS-based science teaching on students' attitudes towards science, creativity skill, and academic achievement was another finding in the present review. Durmaz (2014) also indicated the presence of a significant correlation between the SPSs and the achievements in science; Maranan (2017) asserted that all the basic process skills were significantly related to creative skills. In the present review, 5 (14.70%) of the African articles investigated the effect of SPS on other issues. For example, the impact of process skills application on the scientific attitude of students [28] and the effects of the SPS teaching approach on secondary school students' achievement [40, 41].

Table 3. Summary of the basic issues of SPS studies in Africa from 2002-2021

SPS related issues	Frequency	Authors
Developing science curriculum via SPS	6 (17.64%)	[8, 19, 20, 36, 46, 48]
Developing students' or teachers' SPS	6 (17.64%)	[26, 31, 42, 45, 47, 49]
Determining variables affecting SPS	8 (23.52%)	[21-23, 25, 27, 29, 30]
Determining teachers' or students' views of SPS	6 (17.64%)	[33, 37-39, 42, 50]

Measuring SPS	3 (8.82%)	[24, 36, 44]
Determining the effect(s) of SPS-based science teaching on attitudes towards science, creativity skill and academic achievement	5 (14.70%)	[28, 34, 40, 41, 43]

3.3. Findings on Methodologies of the African Science Process Skill Studies from 2002-2021

Under the findings on the methodologies of the African SPS Studies: the study designs and techniques, the data collection tools used, and the sample groups selected for the studies were reviewed together.

1. The research methods of African SPS studies from 2002 to 2021

The present review ascertained that the majority of science process skill studies demonstrated more interest in quantitative 20 (58.82%) and qualitative research designs 12 (35.29%), whereas the reviewed articles on African SPS studies from 2002 to 2021 showed that the studies did not use mixed research design (Figure 3). Table 4 shows the details of the research methods used by the studies under the two research designs (quantitative and qualitative).

Table 4. The research design/methodologies of SPS studies in Africa across 2002-2021

Research Design		**Methods**	**Frequency (%)**	**Studies***
Quantitative	Experimental	Quasi-experiment	8 (23.52%)	[21, 22, 27, 29, 30, 34, 40, 42]
	Non experimental	Survey	6 (17.64%)	[28, 31, 39, 42, 47, 50]
		Ex post-facto	3 (8.82%)	[40, 41, 46]
		Secondary data analysis	3 (8.82%)	[19, 35, 37]
		Sub-total	20 (58.82%)	
Qualitative	Interactive	Case study	3 (8.82%)	[23, 24, 45]
		Action research	2 (5.88%)	[43, 49]
		Descriptive	5 (14.70%)	[25, 27, 33, 38, 44]
	Non interactive	Review	2 (5.88%)	[8, 36, 48]
		Sub-total	12 (35.29%)	
Mixed	Mixed		0	
Undefined	Undefined		2 (5.88%)	[20, 26]

In addition, 2 (5.88%) of the papers didn't disclose their research methods. However, this indicates that these studies may have preferred to explain data collection instruments at the expense of stating research methodologies. Indeed, this ambiguity may emanate from a lack of researchers' knowledge of research methodologies. That is, any researcher, who has difficulty in describing the research methodology, may tend to use such methodological description.

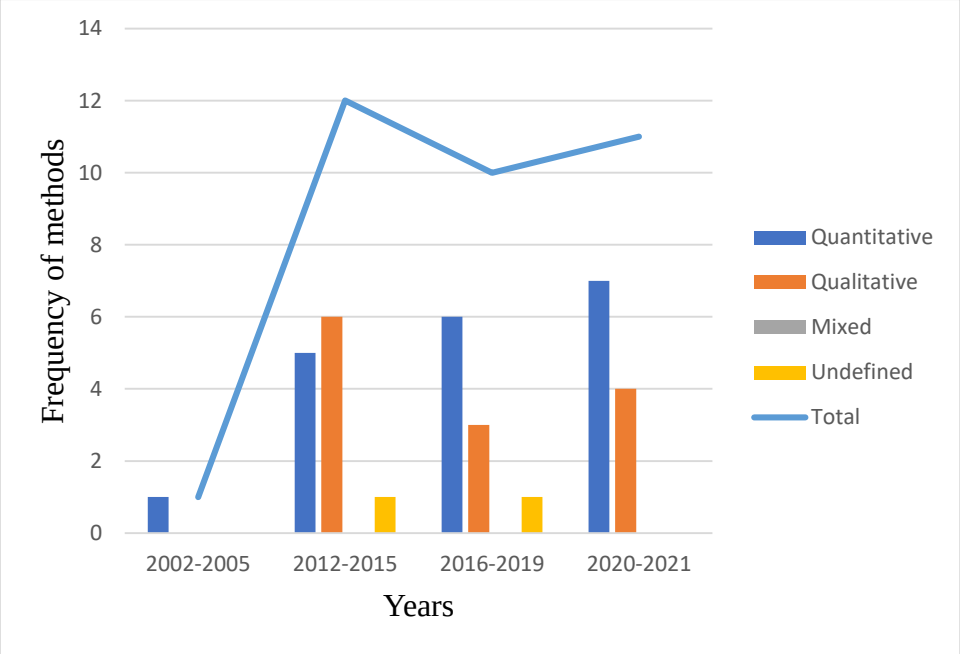

Figure 3. Trends in research designs across years (2002-2021)

As it can be seen from Figure 3, the quantitative design that reached its peak in 2020-2021 was the most frequently used research design starting from 2002 to 2021.In the case of the qualitative approach; it reached the top in 2012-2015. However, the researchers did not show any trend on the mixed design for all years. Figure 3 also displays quantitative research designs that showed a slight increase over the years. But there were small instabilities in qualitative research design.

Data Collection Tools of the Studies under Investigation

This section initially displays data collection tools (Table 5) and then addresses each data collection tool in detail. According to Table 5, the data collection tools used in SPS studies included worksheets/ tests, questionnaires, documents, and interviews.

Table 5. Data collection tools of SPS studies in Africa across 2002-2021

Data collection tools	Frequency *	Authors
Document Analysis	11 (32.35%)	[8, 19, 20, 23, 34, 35, 38, 45, 46, 48]
Questionnaire	8 (23.52%)	[28, 31, 36, 37, 39, 43, 49, 51]
Interview	2 (5.88%)	[38, 43]
Worksheet/Test	16 (47.05%)	[21, 22, 24, 25, 27, 29, 30, 33, 36, 40-44, 49, 50, 52]
Observation	3 (8.82%)	[33, 38, 47]

Frequency * may be more than 34 (100%) because one author can use more than one type of data collection tool.

Questionnaire

Based on the data obtained from the reviewed articles, the majority of SPS researchers, 16 (47.05%) utilized worksheet/tests, and 8 (23.52%) researchers used questionnaires. This might be because questionnaires are comparatively economical and allow researchers to collect data from a large sample, the SPS studies intended to prefer them. For example, Oukoa *et al*. [42] used Biology Practical Teachers' Questionnaire (BBQ) to generate data from the respondents.

Interview

Three (8.82%) the researchers used interviews involving an interactive feeling environment between the interviewer and interviewees. For example, Johannes Ambross *et al*. [33]; used interviews and classroom observations.

Document Analysis

Taking a dual function of document analysis- (as data collection tool and research design) into account, some researchers used document analysis as a data collection tool. 11 (32.35%) studies employed document analysis as a data collection tool to evaluate SPS in documents (i.e., test guide and SPS test results). For example, Oukoa *et al*. [42] analyzed SPS in the Kenya certificate education biology practical assessment approach using document analysis. Likewise, in Nigeria, Akinyemi and Folashade (2010) employed document analysis to evaluate the number of integrated process skills in practical examinations.

Observation

Two (5.88%) researchers recruited observation to unveil the issue(s) under their investigation; for example Ng'andu & Kaulu [47], in Zambia, used observation as a data

collection tool to get information about Chemistry from 5124 practical activity learners of SPS. The other researcher, Geleta [49], observed learners while carrying out practical activities in science process skills assessment instructions (SPSAI) and used observation schedules to record observations.

Worksheet /Tests

Sixteen (47.05%) of the studies used tests with other data collection tools. For example, Akani [24] used the Science Process Skill Test (SPST) for data collection to investigate the levels of possession of Science Process Skills by final year students of colleges of education in the South-Eastern States of Nigeria. And Geleta [49] in Kamise College of Teachers Education (KCTE), Ethiopia also used Science Process Skill Test (SPST). Some of the SPS studies employed at least two different data collection tools (multiple methods) to shed more light on data triangulation. Thus, the researchers tried to have achieved reliability and validity of the data via employing two or more data collection tools for a single study. For example, Sunday and Goodwell (2018) used two data collection tools such as science process skills assessment instruction and observation schedules to ensure the reliability and validity of the study. Because SPS involves both cognitive and psychomotor skills, measuring these skills with only one way of measurement may be a problematic issue. In other words, it calls complementary data collection tools for the reliability and validity of the results to effectively measure and evaluate SPS. In addition, Antwi *et al*. [43] in Ghana used questionnaire , interviews and tests to examine effects of practical work on physics learning.

3. Findings on sample groups of the studies under their investigation

As it can be seen in Table 6, the samples of SPS studies included high school students and teachers, student teachers or pre-service teachers and undefined grade levels. However, it was evident from the table below that most of the studies focused on employing high school students and teachers.

Table 6. The samples of SPS studies in Africa from 2002-2021

Samples groups	Frequency	Authors
High school students	24 (70.58%)	[20, 21, 23, 25-30, 34, 36, 37, 39-47, 50, 51]
Teachers	5 (14.70%)	[23, 24, 31, 38, 48]
Student teachers/pre	3 (8.82%)	[22, 33, 49]

service teachers		
Undefined grade level	3 (8.82%)	[8, 19, 35, 36]

*Frequency may be more than 34 (100%) as the researchers might have used more than on sample group.

Inferring from Table 6, the vast majority of African SPS studies 24 (70.58%) focused on employing high school students as sample groups for their studies. One of the reasons to select such samples may be due to the fact that the suitability of these samples to the type of research carried out (Gul & Sozbilir, 2015). This implies that high school students seemed to be suitable for these educators to their study. Accordingly, the reviewed results of this study showed that the trend of the sample might have been derived from the researcher's ideas because the researchers are more likely to conduct studies with easy-to-obtain data sources. In addition, 5 (14.70%) of the studies focused on teachers, 3 (8.82%) on student teachers, and 3 (8.82%) of them undefined the level of students. But, no study was conducted using middle school and kindergarten students. However, a functional role of the lower grade level education in properly building SPS seemed to be forgotten, Instead of applying SPS on elementary schools where students could learn a lot about it, the researcher have rather emphasized using high school students in their studies, which can be best illustrated by the proverb: - "You cannot teach new tricks to old dogs". In addition, because the role of teachers in developing students' SPS skills is high, future SPS studies should shed light on the application of SPS by teachers' and student teachers.. However, it is worth mentioning that some issues need critical thought, for example, concepts related to how to integrate SPS into all grades (or school years). Therefore, further studies are required to examine the issue further using various samples to make viable comparisons.

4. Conclusions and Recommendations

The present review of SPS studies in African countries showed that the number of African countries that participated in SPS studies from 2002-2021 was low when compared to other continents. Most SPS studies were in Nigeria. The result also indicated that the top three research aims of the reviewed studies were developing a science curriculum via SPS, developing students' or teachers' SPS, and determining variables affecting SPS. However, the role of SPS to increase scientific creativity skills and academic achievement was less studied. With regard to the research design/methods, most of the studies were found to be employing quantitative, whereas some of the remaining studies were observed to be using qualitative research traditions. No paper was detected in employing mixed methods as a research approach. Regarding data collection tools, the most frequently used tools were achievement tests and questionnaires. Concerning the samples, most samples were students at high school

level. Apart from stating how high-level teachers' understanding of SPS skills leads to effective, efficient, and quality implementation of science education at any level, studies synthesized indicated the significance of introducing SPS education in primary education level was almost forgotten as it received little attention from the studies reviewed for this research. In addition, determining (student) teachers' ideas about SPS and developing measurement tools of SPS were also thoroughly discussed.

Recommendations

Inferring from the analysis of the reviewed studies, a notable gap between countries engaged in science process skills research and those with low or no research output was observed. Accordingly, the results of this review suggest that there should still be more studies in different African countries to see the various issues in SPS and improve African science education programs. Further studies are required to check the extent of the relationship between SPS in the development of scientific creativity skills and academic achievement in the African science curriculum. With regard to data collection tools, this review recommends that instead of using one type of data collection tool, such as achievement tests or questionnaire - it is necessary to apply two or more tools together to ensure the reliability of research results. Given the gradually progressive nature of SPS, future studies should pay more attention to start with an early childhood education that dominantly shapes students' learning habits and attitudes towards science. The other things that need attention are, considering a balanced inclusion of SPS in the science curriculum at all levels of education and enhancing quality pre-service and in-service teacher education training programs to raise the development and implementation of SPS in African countries.

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