A Review on Teachers' Understanding of Science Process Skills and Its Importance in Science Education for Africa

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Abstract

This integrative review of literature aims to analyze and evaluate research studies on teachers' understanding of Science Process Skills (SPS) in science education and its importance for the current science education reforms in Africa. The review involved analyzing and synthesizing some research work conducted globally considering the educational significance of SPS and the importance of teachers' understanding of SPS on science education. Then an evaluation of previous research studies from the viewpoints of the science curriculum, teacher education and the 21st Century Learning on SPS education under the African perspective was conducted. Findings in this review showed that teachers' understanding of SPS helps in empowering students to learn science through the application of SPS during the science learning process. Furthermore, findings state that SPS greatly influence not only one's education but also the ability to contribute to economic development positively. However, review findings indicate uneven inclusion of SPS in the curriculum documents as well as during the curriculum implementation at all the levels of science education. Lastly, results display a few studies on teachers' understanding of SPS development in science conducted in African countries. Many of the reviewed studies for teachers' understanding of SPS is on research studies conducted in developed countries. The need for teachers' understanding of SPS to be at a high level and the educational significance these skills cannot be overemphasized. Excellent teachers' understanding of SPS and its implementation in science education can have a positive impact on would be (students) economic drivers and scientist, especially in Africa, where the application of scientific knowledge is still low.

Key words: Science Process Skills, Science Education, Understanding, 21st -Century learning

1. Introduction

1.1 Current Reforms of Science Education in Africa

Currently, many countries in Africa have been making efforts to improve the quality of science education by putting science education at the centre of broader educational goals for society. Various programs and projects, paying attention to scientific and technological development through science education have been instigated in the African continent to enhance economic growth. Some of these programs and projects are implemented in partnership with foreign agencies or Non-Governmental Organizations (NGOs) such as the Japan International Cooperation Agency (JICA) and UNESCO. Science education is supposed to bring about economic development (Kasozi,2006 in Musa Yoldere & Adamu, 2014). There is an awareness that science education can play a role in preparing learners for their future roles in society as responsible citizens. African communities, like any other communities worldwide, have recognized that creative and innovative learning skills are essential for the emerging work environment in the 21st Century. Guided by the Science, Technology and Innovation Strategy for Africa 2024, Aspiration 1 of Agenda 2063, the United Nations Sustainable Development Goals and other frameworks, many countries in Africa have now embraced Science, Technology, Engineering and Mathematics (STEM) education (Global Partnership for Education, 2018). Acknowledging the importance of science education for developing countries, scientific and technologic development requires the development of science education. Science Education provides acceptable standards for people and leads to cultural development (Godek, 2004). It is one of the essential areas of the curriculum. Science education is critical to the development of essential services such as Health, Food, Agriculture, Energy resources, Industry and Technology as acknowledged by UNESCO (Nwosu, 2019). The Environment, Information transfer, Ethics and Social responsibility. Scientific development is the most influential factor in enabling the African continent to enter the mainstream of contemporary technology and commerce (Godek, 2004).

Across Africa, the need is great for scientific answers to the continent's many problems. According to Mutume (2007), countries in Africa lag behind the developed world in terms of scientific capacity and output. Many of Africa's challenges have scientific solutions, but there are fewer individuals engaged in scientific activity per capita on this continent than on any other. Only a handful of African scientists use their skills to capacity or are leaders in their disciplines. Underrepresentation of Africans in scientific practice, discourse, and decision making reduces the richness of intellectual contributions toward hard problems worldwide. It is clear that the speed and quality of the development of science capacity in Africa depends not only on infrastructure and the technical training of people. It's also intimately linked to the quality of people who are able to inspire and lead change.

2. Objective

This article reviews teachers' understanding of the SPS from a global perspective and the importance this is to science education reforms in Africa. The following are the four (4) guiding questions for the study:

1) Why is teachers' understanding of science process skills essential in science education for Africa?
2) Why are SPS important in science education from a global perspective?
3) What is the significance of teachers' understanding of SPS in science education from a global perspective?
4) Have there been any research studies carried out on SPS education in Africa considering the previous research studies conducted under the science curriculum, teacher education development and the 21st Century learning perspectives?

3. Review of Literature

Science education aims to build students' skills and allowing them to apply those skills in everyday lives in a scientific manner (Opulencia, 2011 in Maranan, 2017). Tasks that an individual does proficiently are known as skills. When considered under science education, these skills incorporate SPS. According to Padilla (1990), SPS exemplify a set of all-embracing, interchangeable abilities, suitable to many science disciplines and reflective of a scientist's behaviour. There are two categories of SPS: The Basic Science Process Skills (BSPS) and Integrated Science Process Skills (ISPS). BSPS form the foundation of science learning and include skills that all science learners must acquire. These skills include observation, classification, measuring and using numbers, making inferences, predicting based on observation and experience, as well as communicating. ISPS have a holistic approach to understanding and interpreting a scientific phenomenon. Examples of these skills are controlling variables, making hypotheses, experimenting, interpreting data and formulating models (Padilla, 1990).

Meanwhile, the role of teachers in facilitating the advancement of quality science education through classroom practices is noteworthy. Several studies centering on teachers' understanding of SPS in promoting quality science education with a particular focus on classroom practices have been conducted worldwide. For example, some researchers have pointed out that learners learn more and better science when taught by teachers who recognize the relation between science contents and processes (Novak & Gowin, 1983, Hipkins et al., 2002). It can be contended, therefore, that the teachers should be more knowledgeable and have a better understanding of both the contents and the processes of science. The preceding highlighted practical problems in science education development are compounded by limited research-based knowledge that can inform meaning interventions such as those aimed at improving science teachers' pedagogical skills. Having a basis for investigating teachers' understanding of SPS in Africa, this article reviews the literature on the subject. This review would lead to gaining more information on what previous research work states. It will also be the basis to generate interventions for improving teachers' understanding of SPS, which is cardinal in promoting quality science education. The SPS are all useful in science and non-science situations. Thus, both BSPS and ISPS development in education is relevant to everyone and appropriate for all subject areas in education (Akinbobola & Afolabi, 2010).

Other studies emphasize that teachers' understanding of SPS is vital for improving the quality of education (Harlen, 1997). However, despite several studies establishing the importance of SPS development, it is also reported that teachers do not have adequate knowledge and understanding of these skills. For instance, results obtained by examining teachers' ideas about SPS through open-ended questioning indicate that teachers seriously lack a theoretical understanding of SPS (Karsli et al., 2009). This is a source of concern as the ideal situation requires the teacher to be knowledgeable and understand SPS very well. Additionally, when teachers' knowledge and understanding of SPS is poor learners will have misconceptions of science concepts. One study discovered that teachers were a significant source of learners holding alternative frameworks (misconceptions) on science concepts

(Keraro et al., 2004 in Mutisya, 2015). It is contended that both children and adults cannot use the SPS appropriately (Sunal & Sunal, 2003 in Mumba et al., 2018), which requires knowledgeable teachers to facilitate the acquisition and development of SPS (Chabalengula et al., 2012).

While the above-highlighted research may suggest increasing attention to teachers' understanding of SPS, it appears that this is on research studies conducted in developed countries, and a few from developing countries, especially in Africa. Studies related to SPS conducted in Africa have mainly centred on teachers' views, attitudes (Mutisya, 2015), and perceptions (Rambuda, 2004) and a study on conceptual understanding of SPS (Mutisya et al., 2013) so far.

4. Methodology

The relevant literature was accessed between the period of December 2019 to February 2020 mainly 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”)). Key educational journals from around the world were searched independently. They included the following 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. In this study, science process skills were defined as a set of all-embracing, interchangeable abilities, suitable to many science disciplines and reflective of a scientist's behaviour (Padilla, 1990). Secondly, while acknowledging that science education could be distinct in various ways, in this study, it refers to the field concerned with sharing science content and processes with individuals not traditionally considered part of the scientific community (https://www.igi-global.com/dictionary/science-education/25876). Thirdly, understanding is defined as a psychological process related to an abstract or physical object, such as a person, situation, or message whereby one can think about it and use concepts to deal adequately with that object (Dictionary.com). Lastly in this study, the definition for 21st -Century Learning is learning that enables students to master content while producing, synthesizing, and evaluating information from a variety of subjects and sources with an understanding of and respect for diverse culture (How do you define 21st-century learning, 2010). These search terms were, therefore, satisfactory to capture Teachers' Understanding of SPS development in science education as the central theme of this review. The search was limited to journal articles written in English and whose complete papers were accessible on the databases.

Additionally, the articles were those published between the year 1980 to 2020 because from way back to date, research studies on that the role of teachers in the facilitating scientific skills development in science education has been predominant. In total, 192 articles were found as a result of the initial search. The researcher screened abstracts of these articles to judge their relevance in line with the objective of the review. From this screening process of abstracts, 60 papers are a consideration.

5. Results and Discussion

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

In Africa, there is a pressing need to develop human resources with scientific knowledge and skills required for industrial development, yet children's learning achievements in math and science remain stagnant (Sichangi, 2018). A large contributing factor to this problem is the teacher's unpreparedness to teach these subjects. Even so, there are no adequate training programs to foster knowledge on the topics and help educators develop practical teaching skills. Prominent institutions have raised concerns on Africa's inability to fill most science, technology, engineering and mathematics (STEM) jobs within industries (Global Partnership for Education, 2018). The shortage of such workforce is associated with classroom teaching, and learning practices that are predominantly geared towards passing examinations, and not towards applying knowledge acquired to solve real-life problems affecting societies. Today's students require skills such as collaboration, communication, self-efficacy, citizenship, creativity, and tech-innovation to scale the heights of achieving sustainable development goals. In consideration of the skills highlighted, there is a need for quality science education for Africa. This quality science education can only be provided by teachers whose understanding of science education is at a high level not only in science content but processes too. Teachers' understanding of SPS has a significant impact on the science learning process. When teachers' understanding of SPS is high, they are empowered to promote well-organized, dynamic and operative science learning processes (Miles, 2010)

5.2 Why are SPS important in science education from a global perspective?

Drawing from an analysis of the previous research studies included in this review, four (4) aspects regarding the educational significance of SPS can be acknowledged. Firstly, SPS influence the development of mental and intellectual processes such as

Higher Order Thinking Skills (HOTS) as specified in a study (Hikmah et al., 2018). In support, Choirunnisa et al. (2018) assert that SPS are vital in science learning as the foundation for improving the other more complex skills. Secondly, SPS are necessities for performing scientific investigation. SPS aids the learner in building up competence to search for knowledge and information in the field of sciences through scientific method sustenance (Joseph et al., 2017). The longstanding outcome of learners' attainment of SPS will enable them to discover scientific knowledge by adopting the scientific process (Karsili & Sahin,2009). The third point is that SPS improve scientific creativity and academic achievement/understanding. "SPS improves scientific creativity and academic achievement of learners" (Brotherton & Preece, 1995). In addition to nurturing attitudes toward science, SPS are important elements that may influence students' performance (Maranan, 2017). The fourth point is fostering a positive attitude towards science learning. (Bilgin 2006, in Raj & Devi, 2014) observes that SPS promote positive attitudes towards science among learners. "In other words when students understand the science process skills, science becomes more interesting to them, which increases the positive attitudes towards science" (Zeidan & Jayosi, 2014)

Shown below in a thematic figure 1 ensuing is a summary of the four (4) aspects on the significance of SPS.

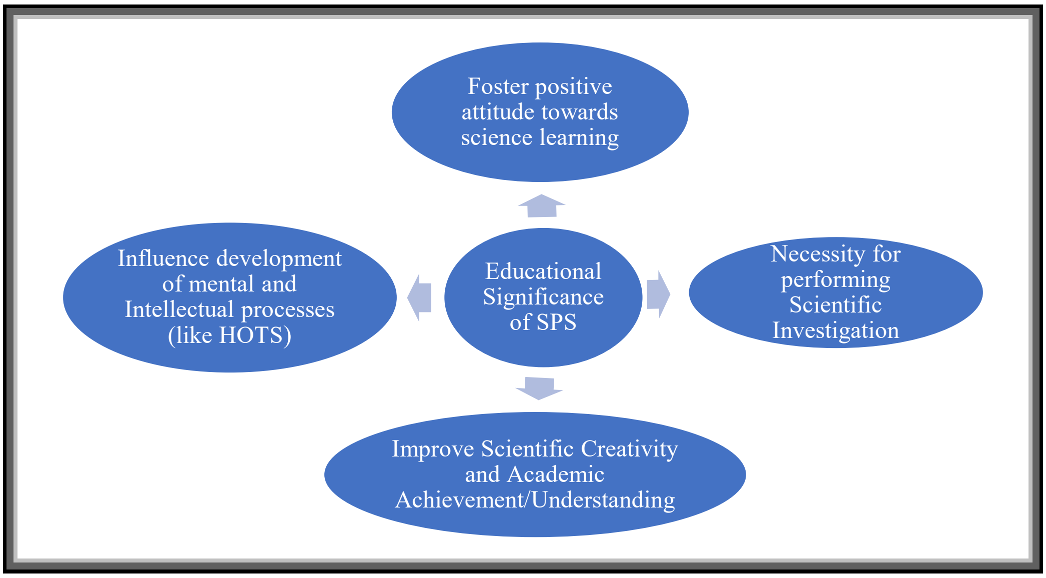

Figure 1. Educational Significance of Science Process Skills

The main finding from the literature review on the educational significance of SPS is that these skills are an essential key factor in the study of knowledge that has an impact on one's science education. These skills help students learn how to learn in the sense that in the learning process, SPS not only serve as the basis of scientific methods but are also an essential aspect in learning about the characteristics of knowledge (Hikmah et al., 2018). Using the SPS, students are aided in developing competence in searching for knowledge and information using scientific methods which would be useful in non – science education sectors and future life pursuits. 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.

5.3 What is the significance of teachers' understanding of SPS in science education from a global perspective?

In this section, an outline of findings on how teachers' understanding levels of SPS contributes to science is drawn. One of the identified contributions is that the learning process turns out to be effective. 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 contribution is the enhancement of an active learning process: Studies revealed that teachers having developed SPS teach these skills more actively in their classrooms (Downing & Gifford, 1996). Improved formative assessment conduct is recorded as a result of SPS influence too. Also supported by research is that there is a positive relationship existing between the cognitive level of questions asked by the teacher and the level of thinking a student experiences in processing an answer (Wilen, 1987 in Downing & Gifford, 1996). SPS have also contributed to the efficiency in the learning process. Teachers should be efficient in their teaching of science as explained in some studies that equipping learners in school with the SPS requires teachers to be familiar with the skills and the method of teaching them (Al-rabaani, 2014). To teach the SPS to students in a well-organized and competent way, teachers should have enough SPS (Miles, 2010 in Bulent, 2015). It is understood that SPS influence mastery of subject matter during the learning process. It is renowned that teachers, especially at preservice level, must be trained in SPS to enable them to teach students to master the subject matter as well as ways of knowledge acquisition in science teaching and learning process (Susanti et al., 2018). Lastly, the influence pointed out is on the teachers' ability to develop students' SPS during the learning process. "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). Besides, 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).

Examples are given in table 1 below to briefly illustrate the citation sources for the evaluation of what teachers' understanding of SPS has on the science learning process.

Table 1. Evaluation of SPS understanding by teachers on the science learning process.

	Facilitates Effective Learning	Enhance Active Learning	Promotes Efficient Learning	Mastery of Subject Matter	Improved Assessment during Learning	SPS Development
Author/Year						
Mutisya et al. (2013)	✓					✓
Downing & Gifford (1996)		✓				
Wilen (1987)					✓	
Miles (2010)			✓			
Susantia, Anwar & Ermayanti (2018)				✓		
Hamidah et al. (2013)						✓

Teachers' understanding of SPS leads to the improvement of learners' ability to use these skills well in their daily life situation. Teachers are to have a high understanding of SPS (conceptual and operational) to enable them to facilitate quality student acquisition and development of these skills during the science learning process (Kruea-in et al., 2015). Teachers' understanding of SPS helps in empowering students to do science through the application of SPS during the science learning process. Students taught by teachers with little understanding of SPS simply follow instructions. These students may gain high marks even though they did not acquire a conceptual and operational understanding of the skills applied in SPS. Creativity and originality, which are hallmarks of scientific investigations, would be difficult to develop from such poor conceptual and operational background (Emereole, 2009). Through the application of SPS, there would be a creation of scientific knowledge by students which they can transfer and apply it later in life. Therefore, teachers' understanding of SPS affects the facilitation of these skills during the science learning process and bears a long-term effect on student science learning.

5.4 Have there been any research studies carried out on SPS education in Africa considering the previous research studies conducted under the science curriculum, teacher education development and the 21st Century learning perspectives?

This section provides an integrated review of research trends conducted on SPS in science education from some developed and developing African countries. The countries are into developed and developing based on the United Nations Development Programmes (UNDP) Country Classification System. The categorization criteria are from the Human Development Index (HDI) calculation done with consideration of the multifaceted nature of development. The review findings are under categories of (1) Science Curriculum Perspective, (2) Science Teacher Education Development Perspective and (3) The 21st Century Skills Development Perspective

5.4.1 *Science Curriculum Perspective:*

The OECD PISA Project emphasized that the science curriculum must not only focus on what is taught but seek to offer ways for students' operational outcomes as a result of their science education (Harlen, 1999). There are three (3) main review findings in this section. 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 as the main factors bearing a negative effect on SPS development in the sciences teaching/learning process (Duruk et al., 1997, Downing & Gifford, 1996, Siachibila & Banda, 2018, Patonah et al., 2018). Secondly, one study findings from a developing nation point out that the variety of using teaching approaches during the science learning process has a positive impact on SPS development (Rauf et al., 2013). Thirdly, the review findings on the trends in research under science curriculum perspective on SPS focuses more on the inclusion of SPS in science curriculum reference and assessment documents. The third finding is the science curriculum implementers' behavioral influence: Attitude towards the science of curriculum implementers such as teachers affects their performance of SPS in the teaching and learning process (Downing & Filer, 1999). Table 2 below provides a summary on the review findings in trend studies on SPS under science curriculum perspective.

Table 2. Research Trends on SPS under curriculum perspective for developed and developing countries

Author, Year, Country	**Country Status**	**Findings**
Duruk et al. (2017) Turkey	Developed	There is an insufficient display of ISPS in the science curriculum.
Downing, J. & Filer, J. (1999) USA	Developed	Teachers' performance in SPS can be affected by their attitude towards science.
Downing, J. & Gifford, V. (1996) USA	Developed	Subjects whose SPS competency is at high-level possess more important questions and raises usage of diverse/ advanced items in teaching.
Siachibila, B. & Banda, J. (2018) Zambia	Developing (Africa)	Examining BSPS is given more preference compared to ISPS in Chemistry Practicals.

The review findings on the trends in research under science curriculum perspective on SPS show that studies focused more on the inclusion of SPS in science curriculum reference and assessment documents. One of the most important goals of the science curriculum is to develop skills which lie under scientific thinking and decision referred to as SPS (Yumusak, 2016). The two categories of SPS; BSPS (Simpler) and ISPS (Complex) are interrelated. They complement 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. SPS inclusion in science curriculum allows students to develop and understand the knowledge of scientific ideas, life operations and skills alongside physical entity through studying the environment/living things. Unfortunately, some previous studies reveal unbalanced inclusion and application of these skills in the science curriculum. It is asserted that BSPS are more represented than ISPS (Duruk et al., 2017).

5.4.2 *Research Trends on SPS in Science Teacher Education Perspectives*

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). 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 that preservice teachers' performance on SPS was reasonable compared to their theoretical knowledge (Chabalengula et al., 2012). The critical role that teacher educators play in helping prospective teachers develop SPS can never be overlooked (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 review findings under this perspective is given in Table 3 below.

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

Table 3. Research Trends on SPS in Science Teacher Education Development for Developed and Developing countries

Author/Year/Country	Country Status	Findings
Foulds, W. & Rowe, J. (1996) Australia	Developed	Brief courses in science education may influence significant SPS development. Nevertheless, a need for further SPS development by considering more robust treatment programs for student teachers.
Chabalengula, V., Mumba, F. & Mbewe, S. (2012) USA	Developed	Preservice teachers' performance on SPS was better than their conceptual understanding of the same skills. This was based on their inability to provide reasonable conceptual definitions and explanations of the SPS.
Karsli, F., Şahin, Ç. & Ayas, A. (2009) Turkey	Developed	Majority of science teachers lack theoretical knowledge about SPS.
Molefe, L., Stears, M. & Hobden, S. (2016) South Africa	Developing (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	Developing (Africa)	Preservice science teachers SPS in integrated science is enhanced using Reflective-Reciprocal Teaching along with the Reflective- Reciprocal Peer Teaching strategies.
Kruea-In, C., Kruea-In, N. & Fakcharoenphol, W. (2015) Thailand	Developing (Africa)	In-service teachers' understanding of SPS is higher than that of the preservice teachers. Despite this, both groups' score for inferring skill is low.

5.4.3 *Research Trends on SPS Education in the 21st Century Learning perspective*

21st-century learning is essential as it involves skills that are used in modern learning, 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 in this rapidly evolving world to be involved in the discussions about the critical technological and scientific activities of the society. The numerous tasks now require advanced knowledge, skills, and productive communication within a community which has raised the need for the development of 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. Acquisition and development of SPS enable students to solve problems, think critically, make decisions, find answers and satisfy their concerns (Remziye et al., 2011). The significance of teaching students SPS is to enable them 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). In table 4 below, a summary of findings from previous studies done in developed and developing countries regards this section is displayed.

Table 4. Summary of Trend Studies findings on SPS in the 21st Century Learning

Author/Year/Country	Country Status	Findings
Demirbaş & Tanriverdi, (2012) Turkey	Developed	SPS have a significant role in science education.
Berge, Z. L. (1990) USA	Developed	SPS learning by students can be promoted when using tools such as a microcomputer, using file-management programs and structured activities.
Abungu, H. E., Okere, M. I. O. & Wachanga, S. W. (2014) Kenya	Developing (Africa)	science process skills 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 champion the development of other skills in science teaching and learning process; thus, learner acquisition of the SPS must not be overlooked in this 21st-century learning era. 21st-century learning is defined as learning that enables students to master content while producing, synthesizing, and evaluating information from a variety of subjects and sources with an understanding of and respect for diverse culture (How do you define 21st-century learning, 2010 in Kayange & Msiska, 2016). SPS are a vital factor that influences not only one's education but how when well acquired and developed by individuals can enable them to make positive contributions to economic developments in this 21st-century era and future life. SPS development through science learning still is a requirement even now 21st-century learning is about interactions between theory and practice, individuals and communities, formal and informal learning, learners and meta-cognitive brokers (Lee & Hung, 2012). In comparison 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.

6. Conclusion

Teachers' understanding of the SPS has a significant impact on science education, especially in the era of 21st-century learning. The high-level teachers' understanding of these skills leads to effective, efficient and quality implementation of science education at any level. Science teachers whose understanding of SPS is at a higher level are good in facilitating the acquisition, development and application these skills by learners during the classroom activities. None of the studies on teachers' understanding of SPS reviewed is from Africa. Besides, many of the reviewed studies on the importance of SPS is on research work carried out in developed countries. This creates a need 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. SPS are an essential key factor that influences not only one's education but how when well acquired and developed by individuals can enable them to make positive contributions to economic developments. It is cardinal that the science education offered in Africa be a means to enhance industrialization, modernization and economic growth in the continent. Hence, the understanding of SPS development and its implementation can have a positive impact on would be economic drivers and scientist in the African context.

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