



**Abstract.** Today science teachers are expected to understand the nature of environmental education, and be competent in skills, methods, and procedures relevant to a science discipline. The purpose of this research was to explore pre-service science teachers' views with regard to environmental education, investigation conducted during a freshwater ecosystem studied, skills developed and the associated stepwise scientific process. Data were collected through a five-item questionnaire that included the characteristics of environmental education, types of scientific investigations, science process skills and the scientific process. 94 students that registered for a Bachelor of Education degree participated in this research. The results from statistical analysis of the teachers' responses showed the importance of life-long learning, involvement of community in environmental education and development of critical and problem-solving skills. However, most teachers could not provide correct scientific investigation they conducted during the freshwater study. Although there were no correlations between the investigation, science process skills and the associated scientific process, influence of the stepwise scientific process recommended in the science curriculum was evident in the teachers' linking of form a hypothesis to observation. The findings imply that teachers face potential challenges in understanding of scientific investigations and the scientific process.

**Keywords:** fieldwork, environmental education, pre-service teachers, science process skills, scientific investigations, stepwise scientific process

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## PRE-SERVICE TEACHERS' VIEWS ABOUT ECOSYSTEM-BASED FIELDWORK IN TERMS OF THE NATURE OF ENVIRONMENTAL EDUCATION, INVESTIGATIONS, SKILLS AND PROCESSES

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### Introduction

Environmental education (EE) had long advocated a multidisciplinary view of an environment, acquisition of skills, knowledge, values, attitudes and solving of environmental problems (UNESCO, 1980). Today programmes related to EE could also be viewed as instrumental in the acquisition and development of skills, affective domain, and human-ecosystem connections (Powell et al., 2019). This is reasonable because explanations based on change in natural systems on earth are key in the understanding of the scientific concepts, processes, and tracing of the origins of environmental issues (Anand, 2013). Amid the issues thereof, EE has since presented a new challenge to teachers (Reddy, 2011), hence a need for the development of their expertise and enthusiasm (Lock, 2010). Thus, it can be argued that acquisition, for instance, of skills, understanding of scientific concepts and of the characteristics of EE, need to be prioritised and developed in appropriate and/or relevant settings to enhance their retention by teachers. Dresner et al. (2014) suggested that with regard to learning and retention of knowledge of the ecosystems, laboratory work and lectures may be supplemented with experiences that are based on field-based research and modelled the scientific process. This argument is reasonable considering that the scientific process is a model to problem solving, particularly in science. It melds with science process skills (SPS), which according to Gultepe (2016) are considered key to science education.

In EE there have been methods and processes to support change-oriented learning towards better environmental sustainability practices and/or environmental learning in a wide range of contexts in South Africa (Fundisa for Change Programme: FCP, 2013; Rosenberg et al., 2008; Shava & Schudel, 2013; Vogel et al., 2013). The learners studying science are expected to critically show responsibility towards the environment and also develop scientific skills and processes associated with investigating natural phenomena (Department of Basic Education: DBE, 2011). Sadly, teachers who are entrusted to develop learners' educational outcomes remain part of education problems in South Africa (Spaull, 2019). In relation to EE, there has been emphasis on the capacity of teachers to implement it (EE) in the curriculum (Reddy, 2011;

FCP, 2013). One would expect such teachers to have competence, for instance, in the knowledge, skills, values, principles, methods and procedures relevant to disciplines (Molefe et al., 2016) such as EE. For these teachers to show such competence, they should understand and value scientific inquiry (J. Lederman et al., 2018). They should also show interest in science and environmental awareness, as well as proficiency in scientific knowledge (FCP, 2013). Most importantly, they should understand that fieldwork is a signature pedagogy for future outdoor EE teachers (Thomas & Munge, 2017), as it also accommodates scientific inquiry (Remmen & Frøyland, 2014).

## Literature Review

The most influential work related to EE can be traced as far as the Tbilisi Conference (Reddy, 2011; Charoen-silpa et al., 2012). EE was then envisaged as an action-based tool of teaching in which development of awareness, knowledge, skills and attitudes "assume[d] their full significance with the problems of the environment" studied through excursions, field work, and study trips (UNESCO, 1980, p. 44). Years on, an emphasis has also been on EE research and the associated study of ecological and issue-related scientific knowledge, empowerment of learners and study of curricula material (Scott, 2009). In other words, EE may be viewed as a key to environmental awareness - a phenomenon supported by Littledyke (2008), Moyo and Masuku (2018) and Soto-Cruz et al. (2014). Furthermore, it (EE) may point to the synergy between inquiry-based learning and ecology (Taylor & Bennett, 2016) as well as the scientific process (Tang et al., 2009; Thomas, 2012) within the context of science education. Finally, it may involve ecology-based training for a pre-service teacher (Gülüm, 2011) and thus development of ecology-based content and SPS (Colley, 2006).

It should be noted that the quality of teachers determines that of an education system (Spaull, 2019). Therefore, it is reasonable that practice of EE showed that the associated programmes that support teachers are key (Eames et al., 2008; FCP, 2013; Reddy, 2011). Thus, EE should be part of science teacher's education for its (EE) characteristics to be enshrined in science education. That said, the definition of the environment itself has long evolved and can now be explained in broader terms (Reddy, 2011). Teachers need to understand the multidisciplinary nature of the environment before they engage in EE. EE itself entails environmental knowledge, which in turn encompasses knowledge and awareness about environmental issues the world is confronted with today as well as the solutions (Boca & Saraçlı, 2019). Thus, the researchers contend that in science education it is important that prior to blending EE with scientific investigations, the scientific process and the associated SPS, teachers' views about its (EE) characteristics are illuminated. Sondergeld et al. (2014) argued that EE should not only integrate multiple content areas but also make education relevant, use social context and promote *lifelong*, forward-looking education. The proposition of lifelong education points to one of the initial characteristics of EE that teachers should understand. The other characteristics include integration of education into community and the interdisciplinary and holistic nature of EE even in its application (Molefe & Aubin, 2021). Its approach to solving problems (another characteristic) dovetails with Ntanos et al.'s (2018) arguments about EE benefits in terms of critical thinking skills and problem-solving skills.

Fieldwork remains a long-standing pedagogy across a range of disciplines in higher education institutions (HEIs) (Thomas & Munge, 2017). It is considered one of the leading mechanisms for teaching and learning and doing science (Allen, 2014). It may also be a relevant method in an "*ecosystem study...a water pollution test, a biodiversity audit and general observations...*" (Rosenberg et al., 2008, p. 2; emphases added) that may be central to enabling pre-service teachers make connections between the domain of observable(s) and that of ideas. The implication is that teaching about ecosystems might provide an opportunity for inquiry learning (Taylor & Bennett, 2016). This explains why the popularity of fieldwork is rooted in its ability to accommodate inquiry-based learning in which students may engage in scientific investigations (Remmen & Frøyland, 2014), understand ecology content knowledge (Colley, 2006) such as that related to biodiversity and pollution (Shava & Schudel, 2013) and SPS (Molefe et al., 2016). In other words, by incorporating scientific inquiry in fieldwork in EE, teachers are first helped to engage in scientific investigations, depending on types or research questions (N. G. Lederman et al., 2013). Secondly, the teachers may be able to apply scientific knowledge in interdisciplinary context. Thirdly, drawing from Ozdem-Yilmaz and Cavas (2016), teachers may also have an opportunity to consolidate scientific processes with scientific knowledge, scientific reasoning and critical thinking to advance scientific knowledge associated with EE. Educators' understanding of scientific inquiry and scientific investigations remains relevant even today. This is even more important considering that the issue of the scientific method and SPS are enshrined in these two concepts (J. Lederman et al., 2018). Thus, it can be argued that the inclusion of scientific investigations in the present research



was important because teachers' development of SPS might be necessitated through them (scientific investigations). The success of the development of SPS may form the basis for their understanding of how SPS blend with the scientific process within an equally understood context - EE.

The role of teachers in their students' development of SPS cannot be overemphasised (Saban et al., 2019). Literature review shows that while SPS remain the key part of research over the last 10 years (e.g., Gultepe, 2016; Molefe & Stears, 2014; Silay & Çelik, 2013; Tilakaratne & Ekanayake, 2017; Yakar, 2014), they (SPS) had long been central to debates on processes and content (Millar & Driver, 1987; Wellington, 1989; So, 2003). Molefe et al. (2016) have elucidated on the debates around teaching and/or development of SPS, conceptual understanding and context. Gultepe (2016) contended that as teaching science encompasses the content and processes and skills, "underestimating content over process or process over content is unacceptable", as both are equally important (p. 780). As referred to earlier, SPS (and thinking or critical thinking skills [Foskett, 2000; Taylor & Bennett, 2016]) can be part of a study of ecosystems (VanLeuven & MacDowell, 2000). Despite criticisms around SPS, their development may improve teachers' understanding of environmental concepts today (Cf. Irwanto et al., 2018). Use of an integrated learning strategy may be effective in developing teachers' SPS and awareness of the river environment (Winarti et al., 2018). Thus, SPS should be linked to EE and engaged in and developed subsequent to conceptual understanding such as understanding of environment in a broader sense using a suitable teaching and learning strategy. Most importantly, they should be linked to the scientific process itself.

### **Frameworks for EE, Scientific Investigations, SPS and the Scientific Process**

Suitable frameworks were needed in the present research because there are various views about concepts used such as EE, scientific investigations, SPS and the scientific process (scientific method). Indeed, literature has different lists of the *characteristics of EE* (e.g., Baez et al., 1987; Charoensilpa et al., 2012; UNESCO, 1980), *SPS* themselves (e.g., DBE, 2011; Gultepe, 2016; Molefe et al., 2016; Saban et al., 2019), *science processes* (DBE, 2011; Moeed, 2013; So, 2003; Watson & James, 2004), as well as *scientific investigations* (Moeed, 2013; So, 2003; Watson et al., 1999).

For teachers to be able to explain natural phenomena scientifically, they should have an environmental awareness (e.g., of the nature of EE). They should not only know the goals and purposes of science investigations but also the types of scientific investigations (Moeed, 2013; Watson et al., 1999). In order to contextualise the present research, the researchers drew from UNESCO (1980), Baez et al. (1987) and Watson et al. (1999) to devise frameworks that might act as a lens for this research with regard to the characteristics of EE and the types of scientific investigations (Table 1).

**Table 1**  
*The Nature of EE and Types of Scientific Investigations*

Characteristic features of EE	Types of scientific investigations
1. It is a life-long, forward-looking education.	(1) Fair testing and comparing
2. It involves integration of education into the community.	(2) Pattern seeking
3. It is interdisciplinary and holistic in nature and its application.	(3) Classifying and identifying
4. It encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills.	(4) Exploring

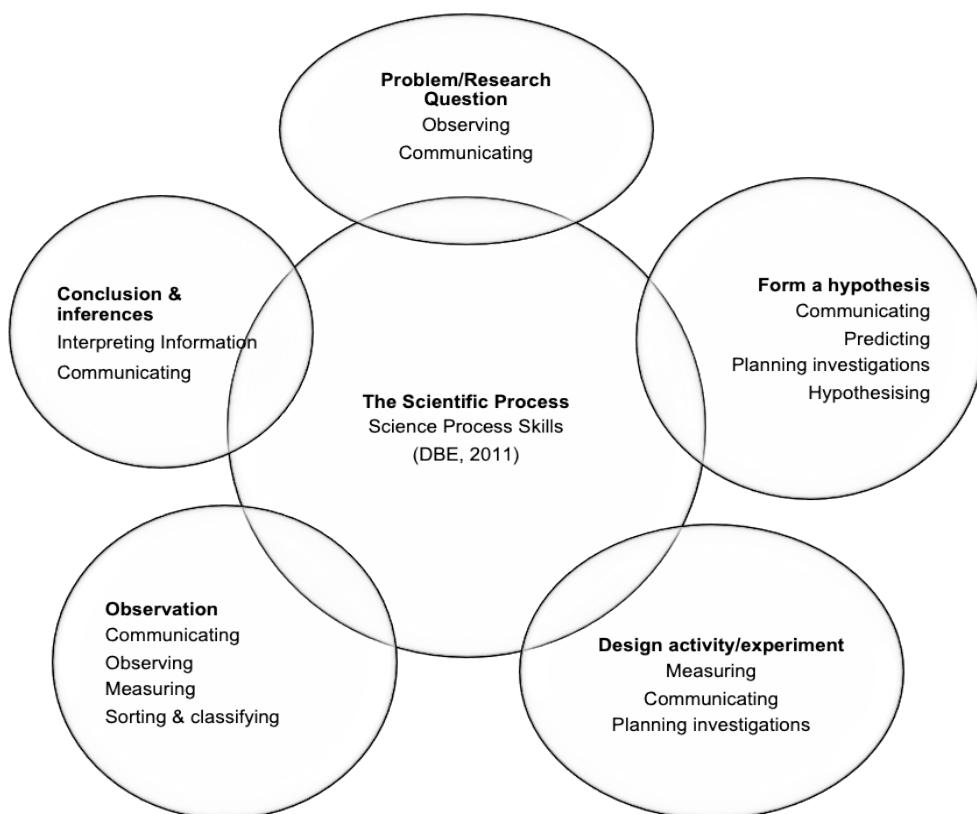
As humanity ventures into the 4<sup>th</sup> Industrial Revolution with its glaring grand challenges, the importance of SPS and environmental awareness cannot be overemphasised, especially in teacher education. Sadly, there are also misconceptions about the associated scientific process, and fair testing is at the centre of them (Moeed, 2013; DBE, 2011). Thus, the misconception around fair testing needed to be diagnosed and corrected. For a framework on skills and the scientific method, they drew from SPS, and the stepwise scientific process stipulated in the South African Natural Sciences curriculum (DBE, 2011). Furthermore, they drew from Molefe and Stears (2016) and Watson and James's (2004) ideas to show how such skills may blend into those scientific processes (Figure 1).

*Research Aim and Research Questions*

The aim of this research was to explore pre-service teachers' views in relation to the characteristics of EE itself, scientific investigations, SPS they developed and the associated scientific process. Many studies analysed by Álvarez-García et al. (2015) have pointed to teachers' indisputable role in "the infusion of EE into schools as a tool to environmentally educate future citizens" (p. 81). Teachers have also been at the heart of empirical work on biology field work for decades (Lock, 2010; Tilling, 2018). Thus, the present teachers were a perfect fit for the research. They studied EE in their Life Sciences module offered at an institution in KwaZulu-Natal, the components of which comprise annual three-day fieldwork in which different ecosystems that include freshwater are investigated. The research has focused on the freshwater ecosystem because it enabled the researchers explore all the key aspects they sought to study.

The research reported here has been more imperative than ever. Global problems and threats in our time include the environment and climate (Ivanov, 2018). Thus, it is important that scientific literacy, interest in science and inquiry-based instruction are incorporated in programmes intended to increase school students' environmental awareness (List et al., 2020). Freshwater is part of a nexus that is proposed as a tool to transform human well-being in Southern Africa (Mabhaudhi et al., 2019; Mpandeli et al., 2018). This is reasonable because about 60% of water used in, for instance, mining and the associated mine dumps and landfills impacts on freshwater, hence biodiversity (Department of Environmental Affairs, 2018). Furthermore, it is through EE in higher education that future teachers could be prepared for a green society today (Boca & Saracli, 2019). Most importantly, this research was part of a project that investigated pre-service teacher learning within science and technology education modules (Molefe et al., 2017), and our latest work on SPS and the scientific process intertwined with global environment issues today.

**Figure 1**  
*The Scientific Process and the Associated Science Process Skills*



*Note.* Adapted from Molefe and Stears (2016)

The research sought to answer the following research questions in relation to an EE module:

- What characteristic features of EE were embedded in the pre-service science teachers' fieldwork?
- What type of scientific investigations were conducted by the pre-service science teachers during their freshwater study?
- What correlations are there between the teachers' views of a freshwater ecosystem in terms of scientific investigations, processes and the associated SPS used?

## **Research Methodology**

### *General Background*

This research adopted a quantitative research approach. The approach allowed the researchers to utilize survey design (Neuman, 2014). Survey designs normally provide a numeric description, for instance, of trends or opinions of a sample of a particular population (Creswell, 2014), which include correlations among variables (Cohen et al., 2018). In this research, a survey administered was descriptive and analytic in relation to the teachers' views about EE, scientific investigations, SPS and the scientific process within the context of the freshwater study. A questionnaire was employed because it is commonly used in SPS-based studies (Fugarasti et al., 2019). Furthermore, it was utilised in this research because it could elicit teachers' views about scientific processes and skills (Coil et al., 2010) and scientific investigations (Moeed, 2013). It could also be used to study learners' understanding of scientific inquiry (J. Lederman et al., 2018).

### *Participants*

Data were collected from 94 pre-service teachers who were registered for a second-year Biological Sciences Education module at the institution. The sample size gave a fairly good reliability because the minimum one (size) that could be used for some statistical analysis is 30 (Cohen et al., 2018). Nevertheless, it should also be noted that this conveniently selected group of teachers completed the questionnaire as part of their fieldwork exercise. Thus, the sample selection might have weakened the research's external validity. The research questions and design of the research were not based on the demographics of the teachers such as those related to gender and age. Thus, these variables were not included. Coil et al. (2010) pointed to the importance of a scaffolding approach and iterative practice, particularly in relation to SPS. The approach and the practice were essential before the present teachers could provide views about EE, scientific investigations, SPS and how they meld with the scientific process steps. Thus, the teachers were suitable participants because they had at least 18 months' exposure to SPS during the relevant method and content module classes and the associated practical activities. These teachers were assured of absolute anonymity.

### *Instrument and Procedures*

A five-item questionnaire created by the researchers was used to establish the teachers' views in relation, for instance, to EE itself, scientific investigations, the scientific process, and development of SPS. The questionnaire, with attached copies of the detailed description of SPS and the scientific process steps (DBE, 2011), and information about EE and scientific investigations, had qualitative and quantitative components. Questions one and two of the questionnaire provided qualitative data on activities the teachers found interesting with regard to the ecosystems they studied, and the descriptions of EE characteristics they learnt, respectively. The *third, fourth* and *fifth* questions provided quantitative data on scientific investigations, SPS, and SPS and the scientific process. In elaboration, with regard to the last three questions, the teachers were expected to select the types of scientific investigations they thought they used during the freshwater study. Second, they selected five SPS used to deduce the quality of the freshwater ecosystem studied. The teachers also provided activities that developed the SPS thereof. Third, they selected two SPS that they viewed to fit into the scientific process steps when investigating the freshwater ecosystem using the chemical test kits. The research explored correlations between the teachers' responses to the questions except the first two.

Survey research is prone, for instance, to measurement and nonresponse errors (Ponto, 2015). Thus, piloting a questionnaire might be useful in addressing issues related, for instance, to clarity and elimination of questions' ambiguities (Cohen et al., 2018). In this research, a pilot test of the questionnaire was conducted with a tutor and ten demonstrators who successfully completed the module. It should also be noted that Molefe and Stears's (2016) findings on SPS, the scientific process and the scientific inquiry were further used to improve the questionnaire for the research. In addition to the improvements made (e.g., the questionnaire sectionalization and itemization), the results of the pilot test were used to revise the questions of the questionnaire where necessary. For example, *investigations* were reworded into *scientific investigations*. The teachers were further requested to provide details concerning SPS they developed during the freshwater study (see the questionnaire's Table 2) and an example was given to enable them to successfully complete the last question on the questionnaire (see the questionnaire's Table 3).

The questionnaire was administered during a fieldwork period. Ethical clearance for the project investigating pre-service teacher learning within science and technology education modules at the institution was used.

### *Data Analysis*

Cohen et al. (2018) pointed to the importance of data entry and cleaning. Such processing of data was conducted using OpenRefine. The data required a statistical package that could enable the researchers to compute descriptive and analytical functions essential to answer the research questions. R was used because of its extensive application in statistical and graphical techniques. For questions concerning EE's characteristic features and type of investigation performed by the teachers, the researchers needed to verify that the answers were not given randomly. Thus, the preliminary results were based on Chi-squared test on the frequencies. Then, Kendal and Pearson correlation tests were used to measure the degree of the relationship between variables of the questions. The tests were corrected using a Bonferroni correction.

## **Research Results**

This research sought to illuminate the teachers' views of the characteristic features of EE (EECF) and scientific investigations prior to exploring those related to SPS and the scientific process. It was important that a test was made to check whether the answers concerning these two variables were given randomly. Chi-squared test was used to compare the given answers to uniform (random) ones. The respective *p*-values (Table 2) show that the answers for EECF and scientific investigations were not given randomly.

**Table 2**  
*p*-values of Chi-squared test for uniformity for EECF and scientific investigations

Variables	$\chi^2$	df	<i>p</i> -value
EECF	32.9	4	< .001
Investigations	57.5	5	< .001

### *Characteristic Features of EE that Were Embedded in the Pre-Service Science Teachers' Fieldwork*

One of the activities that were part of the teachers' fieldwork was a collaborative development of critical thinking skills within the context of nature conservation and sustainability. Hereafter, they were expected to describe any two EECF (Table 1) they had developed before the researchers assessed, for instance, their SPS and values essential for solving environmental problems today.

The uniformity test was followed by further exploration of the dataset. Table 3 shows that the following pair of EECF were given most often: *It is a life-long, forward-looking education and it involves integration of education into the community*. These characteristics together with *It encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills* resulted in the second and third most given pairing, respectively. Some of the written descriptions associated with the results were:



**Table 3**  
*Frequency Table for EECF*

EECF	Frequency
It is a life-long, forward-looking education and it involves integration of education into the community.	29
It is a life-long, forward-looking education and it is interdisciplinary and holistic in nature and its application.	5
It is a life-long, forward-looking education and it encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills.	27
It involves integration of education into the community, and it is interdisciplinary and holistic in nature and its application.	2
It involves integration of education into the community, and it encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills.	24
It is interdisciplinary and holistic in nature and its application, and it is interdisciplinary and holistic in nature and its application.	3

EECF 1 (see Table 1): *It [EE] is always being updated and the information added because new species...are forever discovered by people and studied* (Teacher 1).

EECF 2: *This involves...people taking responsibility of the environment that they live in. This can be done through summits, and programmes could arise that teach people about conservation of nature and sustainability in the community* (Teacher 2).

EECF 4: *Lectures give us platform to gather information for ourselves...This develops and stimulates [sic] our problem-solving and critical thinking skills...Fieldwork taught us awareness and sensitivity to nature; to value every species...* (Teacher 3).

#### *Scientific Investigations that Were Conducted by the Pre-Service Science Teachers during Their Fieldwork*

The freshwater study was intended to build on practical and theoretical emphases on scientific investigations done at the institution. The present teachers' reflections on scientific investigations (Table 1) done enabled the researchers to explore this. The results (Table 4) showed that *Classifying and identifying* (92), *Exploring* (73) and *Fair testing and comparing* (62) were given most often.

#### *Correlations Found Between the Teachers' Views of a Freshwater Ecosystem in Terms of Scientific Investigations, Processes and the Associated SPS Used*

Teachers should be primary creative and critical thinkers concerning solutions to societal issues today. Hence, investigating a nexus of scientific investigations, the scientific process steps and SPS was imperative. The researchers acknowledge that, similar to EECF and scientific investigations, it was important that they presented their findings concerning SPS and the scientific process before those related to correlations between these two variables thereof and the investigations. Nevertheless, it should be noted that this research was a follow-up to one in which they (researchers) studied the present teachers' views about how SPS blend with the scientific process (Molefe & Aubin, 2021). Thus, in this research they chose to focus solely on correlations between several variables (Table 5).

**Table 4**  
*Frequency Table for Scientific Investigations*

Types of scientific investigations	Frequency
Fair testing and comparing	62
Pattern seeking	31
Classifying and identifying	92
Exploring	73
Making things or developing systems	6

*Note.* The students could give more than one answer. Only the marginal frequencies of the given answers were considered.

The researchers computed Kendal's rank correlation tau ( $\tau$ ) and Pearson's product-moment correlation ( $r$ ) to determine the relation between the variables. The results of the Kendal correlation showed that there was a significant positive association between *Form a hypothesis* and *Observation* ( $\tau = 3.28, p = .001$ ). Pearson correlation also indicated the same association between the two variables thereof, which was also statistically significant ( $r = 3.53, p = .001$ ). This means that correlations between the number of incorrect answers related to *Form a hypothesis* and *Observation* were significantly greater than zero.

In relation to SPS, the researchers drew a bar plot of the incorrect answers (i.e., answers far from Figure 1) given by the teachers (Figure 2). The results showed that all the teachers provided less than two incorrect answers out of five answers related to the SPS *observing, comparing, recording information*, and *communicating*, which is a good result. For random answers, they computed the same bar plots of incorrect answers (Figure 3).

The results indicated higher values (from 1 to 5), which shows that answers given by the teachers were clearly better than random answers. The researchers then tested for correlations between incorrect answers given by the teachers and those (number of incorrect answers) concerning the other variables (Table 5). The findings could not show any correlations.

In relation to scientific investigations, the findings could not show significant correlations between the number of incorrect answers given by the teachers and the number of mistakes concerning the other variables.

## Discussion

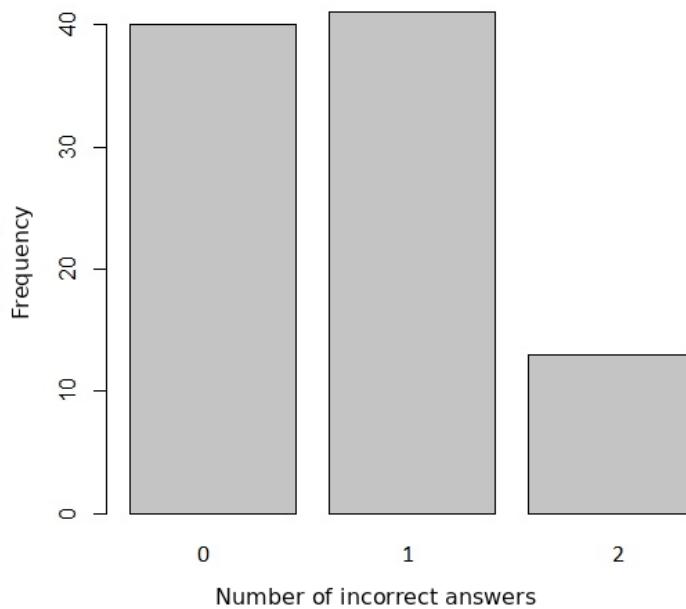
The concept of EE (Baez et al., 1987; Reddy, 2011; UNESCO, 1980), development of skills and knowledge concerning the environment (Colley, 2006; VanLeuven & McDowell, 2000) or using environment (and ICT) (Osman & Vebronto, 2013), the scientific investigations (Watson et al., 1999) and teachers' perspectives thereof (Moeed, 2010) and controversy around the scientific process (Thomas, 2012; Watson & James, 2004) are hardly modern. Nevertheless, EE in tandem with sustainable development have become part of recent key debates on environment at local (Mabhaudhi et al., 2019; Mpandeli et al., 2018) and international levels (Boca & Saraçlı, 2019). Research over the last five years has also focused on SPS and achievement (Prayitno et al., 2017), SPS assessment using scenario based MCQs (Temiz, 2020), understanding of SPS (Shahali et al., 2017), phases of inquiry (Pedaste et al., 2015) and inquiry skills by future biology teachers (Čípková & Karolčík, 2018), context and the debates around teaching and/or development of SPS, and conceptual understanding and context (Molefe et al., 2016). However, teachers' views of the freshwater ecosystem in terms of EE, scientific investigations, processes and the associated SPS they used remains a domain that is hardly been ventured into. This research sets a precedent of aspects that another research may learn from.

**Table 5**  
*Correlation Matrix for the Scientific Process, SPS and Scientific Investigations*

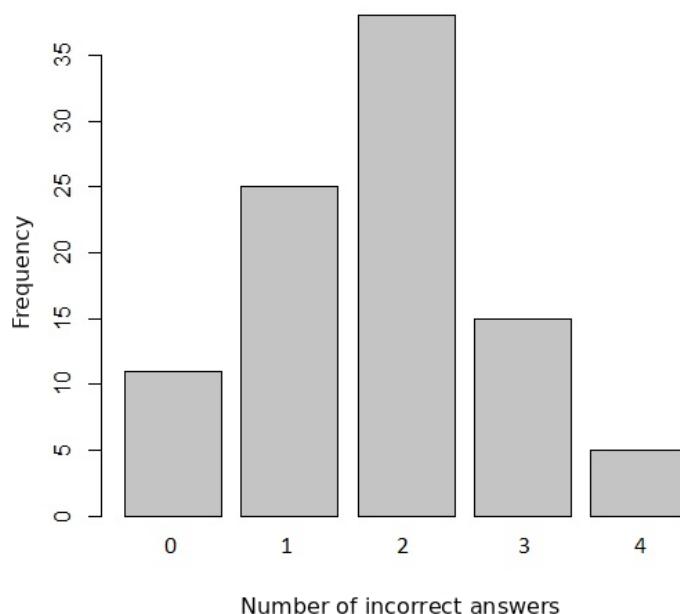
	Research question (ReQ)	Formulating hypothesis (FoH)	Designing experiment (DeE)	Observations (Obs)	Conclusions (Con)	Science process skills (SPS)	Scientific investigations (Inv)
ReQ	1.000	-.212	-.004	-.121	-.059	.011	.045
FoH	-.212	1.000	.038	.345	-.020	.086	.207
DeE	-.004	.038	1.000	-.212	.224	-.062	.037
Obs	-.121	.345	-.212	1.000	-.019	-.080	-.145
Con	-.059	-.020	.224	-.019	1.000	.024	-.131
SPS	.011	.086	-.062	-.080	.024	1.000	-.055
Inv	.045	.207	.037	-.145	-.131	-.055	1.000

Note. The Bonferroni correction,  $.05/21 = .002$ , enabled the researchers to reject a null hypothesis of randomness if the  $p$ -value was less than .002.

**Figure 2**  
*Bar Plot of Answers from the 94 Teachers*



**Figure 3**  
*Bar Plot of Random Answers from the 94 Teachers*



EE might be instrumental in the delivery of various benefits related to natural ecosystems (West, 2015). An environment itself can be used to develop SPS (Osman & Vebrianto, 2013). Thus, it can be argued that studies related to natural ecosystems should include investigations using SPS. Students' ecosystem-based worksheet might not only be practical, but it could be used to enable them to develop SPS (Patresia et al., 2020). The present teachers engaged in a fieldwork where activities included the use of a worksheet and several resources such as bug dials to investigate the quality of the freshwater ecosystem. They were also challenged to reflect on characteristics of EE they developed

and the scientific investigations they employed as the basis for development of SPS using a stepwise scientific process.

The present teachers viewed EE as a *life-long, forward-looking education that involves integration of education into the community*. They went further to pair these characteristics of EE with *It encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills*.

Extensive literature reviewed by Álvarez-García et al. (2015) pointed to challenging issues around environmental competences and the associated teacher training. The researchers were conscious of such challenges in the present research. Thus, the freshwater study was set to nourish life-long environmentally literate habits such as outdoor experience and collaborative work on meaningful environmental issues (Sondergeld et al., 2014). They also tapped into the teachers' critical thinking skills in terms of nature conservation and sustainability in tandem with communal and ecosystem-based impact of mining where they conducted their fieldwork. The associated activity also tapped into their sensitivity, awareness and conscience and reinforced the theoretical EE aspects developed at the institution. The impact, for instance, of critical thinking (Arslan, 2012; UNESCO, 1980), the need to raise awareness of sustainable development and understanding of environment in a broader sense (Reddy, 2011) had long been associated with EE. The results of the present research may thus be understood with regard to guided inquiry and problem-solving processes as the means for life-long learning (Burbules et al., 2020), the importance of development of skills of life-long learning in promoting sustainability (Yli-Panula et al., 2020), critical thinking and problem-solving as key aspects in sustainability and for future success and survival (Taimur & Sattar, 2020) and the need to raise awareness about key issues facing the planet today.

The importance of an iterative approach to science investigations and the associated SPS, conceptual understanding and reflexivity cannot be overemphasised (Chirikure, 2019). It is thus reasonable that there has long been a call for research on understanding of scientific inquiry rather than mere "doing" of it (inquiry) (N. G. Lederman et al., 2013). The experience of developing SPS during the freshwater study was meant to provide the teachers with a framework and understanding of scientific investigations. The results showed that *Classifying and identifying, Exploring and Fair testing and comparing* dominated the selections made by the teachers. It should be noted that the teachers drew from *observed* indicator species to deduce the state of the freshwater ecosystem they studied. They captured, identified, and classified those species according to their sensitivity to pollution using resources provided.

An investigation phase of inquiry may be characterised by "explore" or "exploration" (Harlen, 2014; Pedaste et al., 2015). It should be noted that understanding scientific inquiry itself has been a challenge for teachers and learners (J. Lederman et al., 2018). *Exploring* (Table 4) involves making careful observations over time (Watson et al., 1999, 2006). Exploring might not be as common as fair testing and classification in the later years of an education system (Moeed et al., 2016). Thus, the wrong selection of *Exploring* by the present teachers may be understood in terms of investigating (rather than making observations of) indicator species to deduce the state of the freshwater ecosystem studied. This finding, by virtue of being the second most selected type of scientific investigation, requires further research. On the other hand, the incorrect *Fair testing and comparing* may be understood in terms of emphasis on scientific investigations in the South African Natural Sciences curriculum that are tailored to fair testing (DBE, 2011). Bias towards fair testing is also found in Hume and Coll (2010) and Moeed (2010, 2013). The present teachers' mixed views concerning the scientific investigation they developed suggest possible lack of or limited experience of scientific investigations in high school (Kazeni et al., 2018; J. Lederman et al., 2018) and/or at tertiary level (Molefe & Stears, 2014). That might have, in turn, impacted on their understanding that there is no linear approach to solving problems, especially those related to the environment in a broader sense. The researchers believed that such a deficiency might also impact on the teachers' conceptual understanding of SPS and the scientific process, both of which are equally emphasised in the curriculum. But there was no correlation between incorrect answers given by the teachers on scientific investigations, SPS and the scientific process.

Teachers' understanding of scientific processes might be a fundamental facet of thinking synonymous with science and EE - a reason SPS could also be considered as life-long learning skills (Temiz, 2020). Molefe and Aubin's (2021) results from statistical analysis of the present teachers' responses to skills they developed during freshwater study showed prominence of *observing*. This is a SPS that has been rated highly at the institution (Molefe et al., 2016). Furthermore, teachers might be successful in identifying the skill (Gultepe, 2016). In relation to the stepwise scientific process, the teachers' responses showed a good proximity to the expected representation of the scientific process model (Figure 1) with regard to *Form a hypothesis*. On the other hand, *Observation* showed a relatively close proximity to the model.

As referred to earlier, answers given by the teachers concerning SPS were better than random answers (Figure 3). Teachers' perceptions of understanding of integrated SPS such as *hypothesising*, might be high (Hafizan et al., 2012) contrary to their conceptual knowledge (Mumba et al., 2018). That said, there was no correlation between incorrect



answers given by the present teachers concerning SPS and those concerning the other variables, including the scientific process steps (e.g., *Form a hypothesis* and *Observation*). A significant correlation was only evident between *Form a hypothesis* and *Observation*. Thus, the correlation merely enabled us to understand the direct link between the incorrect answers given by the teachers in relation to the scientific process steps. First, the link between the two steps may be understood in terms of the scientific process being viewed as making "*observations to test the hypothesis*" and drawing a conclusion in support or otherwise of the tested hypothesis" (Moeed, 2013, p. 541; emphases added). The association of the two steps is also evident in the Natural Sciences curriculum (DBE, 2011; also see Figure 1). Teachers are expected to make inferences from their *observations*, make some conclusions, with their *hypothesis* in mind.

SPS have been extensively researched in literature. The popularity of SPS today is reasonable because they are not only the life-long learning skills, but their development is a fundamental goal of science education (Tamiz, 2020). They may enable teachers to not only understand information better, but also develop their critical thinking skills and decision-making (Hafizan et al., 2012). The environment remains an outdoor laboratory to develop them (SPS). Yet, research on their (SPS) association with scientific investigations, the stepwise scientific process and EE is very limited. Buchanan et al. (2019) argue that teachers need to make connections to the scientific method, real-world issues, learning and action when engaging with digital technologies for environmental purposes. Their argument, coupled with the current research's findings, suggest a sustainable future that will disrupt the notions of the science education curriculum.

Lortie's (1975) long-standing views about teacher educators' praxis and its impact on teachers' learning through own "apprenticeship of observation" have now assumed even greater importance. The present findings imply that teacher training should offer apprenticeship that embodies development of life-long skills and 21<sup>st</sup> century skills. The training should also value integration of education into the community.

It was interesting that there was only a link between two scientific steps - *Form a hypothesis* and *Observation*. Students might be confronted with some challenges when conducting scientific investigations (Ramnarain, 2011). Indeed, the present research suggested an influence of science curriculum on teachers' understanding of the scientific process and scientific investigations. Teachers need to understand the fundamental aspect of scientific investigations, that is, our observations of natural phenomena (and scientific investigations) are inspired and guided by problems or questions (N. G. Lederman et al., 2013). Therefore, not all scientific investigations would be based on formulated hypothesis as they (investigations) might be solely rooted in, for instance, the *Classifying and identifying* type (Table 1). For teacher educators, the findings pointed to a need for new ways in which they might better enable their students to reconcile the understanding of types of scientific investigations, SPS and stepwise scientific process.

## **Conclusions and Implications**

The research showed that EE might be viewed as a life-long, forward-looking education that involves integration of education into the community. The research further pointed to the importance of the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills in relation to the two characteristics of EE thereof.

Classifying and identifying, exploring and fair testing and comparing were the common types of scientific investigations selected by the teachers although they simply observed, identified, and classified indicator species according to their sensitivity to pollution in the freshwater ecosystem studied. The results, particularly in relation to fair testing, indicate that the teachers did not succeed in providing the scientific investigation they employed. The results further show a significant relationship between the teachers' ability to formulate a hypothesis and observation.

In this research, it was concluded that EE within the context of teacher education should be characterised by skills development and integration of education into the community. Scientific investigations (and the scientific process) should be part of EE-based teacher education, particularly because teachers might have misconceptions about them. Thus, there is an urgent need for educational reform in higher education in relation to scientific investigations, pre-service teachers' understanding of SPS and how they (SPS) meld with the stepwise scientific process.

The present findings make a small but significant contribution to science education in terms of debates on the areas teacher educators should prioritise when investigating pre-service teachers' stance on EE, scientific investigations, scientific skills and processes intertwined with possible challenges related to the planet's natural ecosystems today.

## **Declaration of Interest**

Authors declare no competing interest.

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# BIOLOGICAL SCIENCE FOR EDUCATORS

## EDUCATIONAL OUTCOMES DEVELOPED DURING LECTURES AND AT ISMANGALIZO

Student Name & Surname	
Student Number	

**QUESTION 1:** Please (a) **describe** the activity that you performed at \*iSangaliso that you found the **most interesting**, and (b) give **reasons** why you chose it.

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Note. \*iSmangalizo is a pseudonym for a place where the students participate in annual three-day fieldwork based on five ecosystems (i.e., Freshwater, swamp mangroves, dunes, natural forest, and plantations) and nature conservation and sustainability activity.

## **QUESTION 2: The Nature of Environmental Education**

## **Characteristics of Environmental Education**

It is a life-long, forward-looking education.

It involves integration of education into the community.

It is interdisciplinary and holistic in nature and its application.

It encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills.

Please **briefly describe** any **two (2)** of the characteristics of Environmental Education stated in the table above. Your descriptions should be based on the **development of the two selected characteristics during lectures** (at university) **and fieldwork** (at iSmanqalizo).

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**QUESTION 3:** Table 1 below shows different types of scientific investigations. Please tick (✓ ) **scientific investigation(s)** that you used during freshwater study at iSmangalizo.

**Table 1 Types of scientific investigations**

ITEM	List Of Types Of Scientific Investigations	Tick (✓ )
3.1	Fair testing and comparing	
3.2	Pattern seeking	
3.3	Classifying and identifying	
3.4	Exploring	
3.5	Making things or developing systems	

**QUESTION 4:** Science process skills in Environmental Education

Please refer to the attachment on science process skills (SPS). It has SPS that you should have developed during the freshwater study.

Please list any **five (5) science process skills** (in Table 2 below) that you developed during your fieldwork at iSmangalizo. You are also expected to provide an activity that you did to support your choice of the SPS.

**Table 2 Science process skills developed at iSimangalizo**

Science process skill I developed	The activity I did to develop this skill
1.	
2.	
3.	
4.	
5.	

**QUESTION 5:** During your freshwater study, you did not use Chemical Test Kits (CTK) for testing water quality at the stream studied. If you did, you would have followed the six (6) processes of science in Table 3 below.

Please refer to the attachment on science process skills (SPS). It has Science process skills (SPS) that you would have developed during the activity, now using the Test Kits.

Complete Table 3 by writing down any two (2) SPS that you would have developed in 5.1 to 5.6. **NOTE: I have done 5.2 for you as an example.**



**Table 3 Processes of science and the associated SPS**

ITEM	PROCESSES OF SCIENCE PROCESSES OF SCIENCE	Two Science Process skills I would have developed
5.1	<b>Problem/Research question:</b> Identify a problem and develop a question. What is it you want to find out about the stream?	
5.2	<b>Research/Background knowledge:</b> What is it that you know about the stream from previous investigations/publications?	Communicating Interpreting information
5.3	<b>Formulating hypothesis:</b> A hypothesis is your idea, answer, or prediction about what will happen and why, when you test the state of the stream's water.	
5.4	<b>Design an activity or experiment:</b> Activities you do to test your idea or prediction to see if you were right about the state of the stream.	
5.5	<b>Observation:</b> (a) Observe/note changes/reactions (e.g., change in colour of the chemical used), and record your observations (e.g., onto a graph, table, etc.), (b) look at the results of your activity or experiment, (c) and write about what happened.	
5.6	<b>Conclusion:</b> Make inferences about the observations recorded. Make some conclusions. What did you find out? Do your results support your hypothesis? What did you learn from this investigation?	

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