A STUDY OF YEAR THREE AND YEAR FOUR SCIENCE EDUCATION STUDENT TEACHERS' NATURE OF SCIENCE BELIEFS AND THEIR SCIENCE TEACHING AND LEARNING BELIEFS

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ABSTRACT

The purpose of this study was to determine the nature of science (NOS) beliefs, science teaching and learning beliefs held by year-three and year-four science education student teachers, and how those beliefs related to each other. The study was underpinned by the epistemological development theory. Researchers conducted a quantitative study involving one hundred and eighty-four year-three and year-four students enrolled in a four-year Bachelor of Education degree. The study revealed that: (i) year-four student teachers held significantly more sophisticated NOS beliefs than year-three students; (ii) year-four science teaching and learning beliefs were significantly "reformed oriented" than year-three students, and (iii) no statistically significant correlation existed between the year-three respondents' NOS beliefs as against their science teaching and learning beliefs. However, there was a statistically significant linear association between the students' NOS beliefs and their science teaching and learning beliefs at year-four level.

Keywords: Epistemology; nature of science (NOS); student teachers; science education

INTRODUCTION

Over the last few decades, numerous research on teacher beliefs have aimed to explore teachers' beliefs related to their practice or to examine changes in their beliefs because of the intervention of teacher education programmes (Fives and Buehl 2012). In particular, Lunn Brownlee et al.

(2017, 192) observe that "there is a large body of research spanning the last four decades investigating the beliefs individuals hold about knowledge and knowing (epistemic beliefs), and the influence of these beliefs on learning approaches and outcomes." Sharing this sentiment, Luft and Roehrig (2007) contend that research investigating teacher beliefs in teacher education institutions where use of inquiry teaching and constructivist practices are encouraged, has been on rapid increase recently. Central to this line of research is the belief that understanding student teachers' beliefs is critical if the teacher education programmes can assist in science teachers' continued development (Luft and Roehrig 2007) as teachers' beliefs "act as filters through which all relevant learning and information used to prepare teachers to act in the classroom are influenced" (Al-Amoush et al. (2013, 465). Similarly, Mansour (2013) contends that teacher beliefs shape teachers' thinking and how they use their instructional strategies in science classrooms. Because of the teacher beliefs' direct influence on teachers' classroom practices, understanding student teachers' beliefs about science could provide teacher trainers "with crucial information for better understanding their candidates' actions, not just in classroom situations but also when planning and structuring pre-service and in-service teacher education units" (Al-Amoush et al. 2013, 466).

Drawing on the view that teachers' NOS beliefs could influence classroom practice, Vhurumuku (2015) investigated how the beliefs science student teachers hold about the nature of inquiry interacted with their teaching practices in their science classes, and how some of the factors facilitated or hampered the translation of these beliefs into classroom practices. Kutluca and Aydın (2017) also investigated changes in student science teachers' NOS beliefs, as well as their attitudes toward NOS, argumentation, and science instruction after having participated in explicit NOS and socio-scientific argumentation processes. Uslu (2018) on the other hand, explored how student teachers' instructional approaches related to their epistemological beliefs. In a related study Bayraktar (2019) looked at the possible correlation between student teachers' personal epistemologies and their attitudes toward science, while Lokollo, Hernani, and Mudzakir (2019) investigated whether or not seniority in the programme had any effect on chemistry student teachers' views about NOS and technology.

Recently there has been a rise in research on student teachers' personal epistemologies and science teaching and learning beliefs (Dorsah et al. 2020; Erixon et al. 2023; Korom, et al. 2025). Most of this research sought to determine how student teachers' personal epistemologies and their teaching and learning beliefs changed during their training.

Some of this research has found that when student teachers start teacher training, they already hold beliefs that excellent teaching is closely tied to the teacher's content knowledge and the teacher's ability to transfer that knowledge to others (Ferguson and Braten 2018). On the other hand, some studies have found that student teachers' ideas about how knowledge is acquired have evolved prior to their enrolment in teacher education programmes (Cheng et al. 2009). Furthermore, some of the research findings have also indicated a correlation between the teachers' teaching and learning conceptions and their personal epistemologies (Sahin, Deniz, and Topçu 2016). These studies have found that student teachers with advanced personal epistemologies have a tendency to employ student-centred teaching strategies, while those with naïve personal epistemologies tend to utilize teacher-centred practices (Epler 2011). Other studies have also found that student teachers with advanced personal epistemologies emphasize the importance of practical work, application of knowledge, learners' experiences, and problem-solving in their science classes (Çam 2015). On the other hand, student teachers with naive epistemological beliefs have been found to adopt teacher-centred methods associated with lecturing, demonstrating phenomena to students, and engaging learners in teacher-led debates (Epler 2011) as well as being fundamentally knowledge transmitters (Chai, Teo, and Lee 2010).

When taken into consideration, these studies seem to suggest that understanding student teachers' conceptions about knowledge, as well as their views about teaching and learning is critical for teacher educators because it will inform them on how they should design curricula that take into account their student teachers' beliefs. Within the South African context, student teachers have been observed during teaching practice to be teaching in a manner that contradicts the science curriculum – which expects them to exhibit a broader view of scientific literacy. According to Hodson (2008) for teachers to be considered scientifically literate they ought to understand what science is and how it evolves over time as it responds to socioeconomic and cultural influences. The curriculum expects teachers to examine and discuss the nature of the problem under investigation, to develop learners' higher-level reasoning skills, to engage learners in a scientific argumentative discourse, and to explore their learners' assumptions and beliefs while engaging them in science knowledge construction (Education 2011). Observations of classroom teaching at both year-level three and year-level four, however, have shown that lecturing and ignoring students' opinions are the most common strategies of teaching used by student teachers. These teaching strategies are employed, contrary to the recommended constructivist teaching and learning approaches which emphasize the value of learners' prior beliefs and their active engagement in knowledge construction (Mansour 2009). This neglect of curriculum reforms demonstrates that the student teachers still value traditional teaching and learning practices over curricular innovations. Tarmo (2016) attributes this to teachers' tendency to use teaching strategies similar to those that were used by their teachers. This suggests that teacher education could be having very little effect on student teachers' perceptions of learning and teaching.

STATEMENT OF THE PROBLEM

Student teachers' beliefs are developed and shaped by their diverse background and upbringing as well as their educational experiences (Spangenberg and Myburgh 2017). In the not-so-distant past, students of different race groups in South Africa could not attend classes together. However, this is no longer the case as South Africa has since introduced a single education system that is democratic and advocates equal education opportunities for all its citizens (Spangenberg and Myburgh 2017). Nonetheless, in general, current student teachers from historically disadvantaged schools were taught by teachers who were products of the apartheid education system which advocated the view of knowledge as absolute. When students believe that knowledge is absolute, they subscribe to the belief that the source of information is an unquestionable authority (Hand, Lawrence, and Yore 1999). This view was inculcated into these in-service teachers during their school days through pedagogies that promoted it.

Currently, there is relatively little that is known regarding NOS beliefs and science teaching and learning beliefs that student-teachers who are products of schools that were disadvantaged under Apartheid hold (van Laren and Moore-Russo 2014), especially in their senior years of study as they prepare to exit their study programmes to join the teaching work force. During these later years of study, student teachers begin to see how their beliefs interact with their classroom actions.

Recognising that beliefs held by teachers play an enormous role in mediating educational change could go a long way in explaining the practices of student teachers from historically disadvantaged backgrounds which have been observed to contradict prescribed curricular practices. Thus, the purpose of this study was to compare the NOS beliefs and teaching and learning beliefs that science education student teachers at two different year-levels hold and how these beliefs related to each other. This study was conducted at one of the rural Universities in South Africa with year-three and year-four students enrolled in a four-year Bachelor of Education (B.Ed) programme, with Science and Mathematics as their specialisations. In this programme, students start with school practicum in their year-three level of study, which is subsequently followed by another period of school-based teaching practice at year-four level. The study sought to compare NOS beliefs and teaching and learning beliefs of two independent groups of students who had just started their school practicum at year-three level and those who had done their last year (year-four level) of school practicum. The difference between the year-three and year-four students' NOS beliefs and their science teaching and learning beliefs could be an indication that various learning experiences that the students were exposed to after year three, including reflections on their practice teaching, contributed to the development of their beliefs. Accordingly, this study sought to find out if student teachers demonstrated any noticeable differences in their NOS beliefs and their science teaching and learning beliefs in later years of their studies. Knowing how science education students in year-three and those in year-four demonstrate these beliefs and how these beliefs relate to one another is very important. This knowledge will inform the curriculum designers about the beliefs students hold in the senior years of their studies. According to Mansour (2009) sophisticated students' personal epistemologies and their teaching and learning beliefs evolve in phases following their experience with both the theory and the practical components of their study.

More specifically, the study aimed at answering the following main question: How do B.Ed student teachers' beliefs compare at different levels of their studies? The sub-questions were:

- Do science education student teachers in year-three and year-four differ
    - in their nature of science (NOS) beliefs and
    - in their teaching and learning beliefs?
- Does any correlation exist between science education student teachers' NOS beliefs and their science teaching and learning beliefs?

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

According to Lederman et al. (2002, 498), "NOS refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development." In this vein, Lederman et al. (2002, 498) see the important aspects of NOS as (a) "acceptance of the tentative nature of science knowledge, (b) understanding that science knowledge is empirically generated and influenced by the social and cultural environment from which it was generated and involves human inference and creativity". According to Borda et al. (2009, 161), "epistemology was first conceived as a branch of philosophy concerned with the nature of knowledge and knowing". On the other hand, Adak and Bakır (2017, 135) describe epistemology as "one of the basic structures of philosophy which analyses the nature of human knowledge, scope of knowledge, its origins, limitations, conceptual components, accuracy and validity in all respects." However, from the psychologist perspective, epistemology refers to "students' beliefs about the nature of knowledge and knowing" or epistemological beliefs (Borda et al. 2009, 161).

To understand how students' epistemological beliefs develop, it is import to draw from William Perry who was the first to study student beliefs from a developmental point of view (Hotulainen and Telivuo 2014). In his developmental model, Perry contends that as people's ability to generate meaning matures, they go through a specific sequence in their notions about knowledge and knowing (Hofer 2001). Perry discovered that students' personal epistemology evolved in four stances, he labelled them as "dualism, multiplism, relativism, and commitment" (Tanriverdi 2012, 2636). He argued that when students first enter university, they tend to believe that information is simply handed down by authority. However, as they move through the years and reach their senior years of study, their beliefs change (Epler 2011).

According to Perry's research, personal epistemologies grow and become more sophisticated when people become less dependent on experts for information and, instead, begin to depend on information they construct to develop an understanding of their own (Jackson 2010). Bromme (2005) sees this progression as representing a person who is transitioning from a dual understanding of knowledge to embracing a relative understanding of knowledge. When a learner adopts the relativistic viewpoint, he or she transforms from a learner who passively receives knowledge to a learner who actively constructs his or her own knowledge (Bromme 2005). From this perspective, Kuhn, Cheney, and Weinstock (2000) contend that the formation of students' epistemological views can be regarded as a process in which the subjective component takes precedence over the objective dimension.

Finding some flaws in Perry's conception of epistemological beliefs, Schommer (1989) conceptualised them as a "belief system that is composed of several more or less independent dimensions" and averred that people may hold sophisticated and naïve beliefs simultaneously. Several research findings have confirmed the development of multidimensional epistemological beliefs. For example, Mihladiz, Duran, and Dogan (2011) discovered that science student teachers' epistemological beliefs evolved more or less independently, and as a result, they had a variety of epistemological ideas that became more relativistic as they approached graduation (Sing Chai, Teo, and Beng Lee 2009). Research has also found a strong correlation between teachers' personal NOS epistemologies and their teaching and learning beliefs (Otting et al. 2010). In contrast Mansour (2013) found anomalies between teachers' personal epistemologies and their conceptions of teaching. These contradictory research findings pose very interesting questions about the programme from which the researchers would want to find answers.

RESEARCH METHODOLOGY

Research Design

According to Kumar (2011, 95) a research design is "a plan, structure and strategy of investigation so conceived as to obtain answers to research questions or problems" In this study, researchers utilised a cross-sectional design. De Vaus (2007, 170) posits that "a cross-sectional design contains three distinguishing features: no time dimensions; dependence on existing differences rather than change following intervention; and groups based on existing differences rather than random allocation." In this study, data were gathered at a certain point in time. The analysis of results focused on existing differences rather than changes in science teaching and learning beliefs and NOS beliefs of year-three and year-four science education students at a specific period. Rather than tracking a group of individuals over time and seeing how those individuals changed, the study sought to obtain comparable existing differences between the two independent groups at a point in time.

Sampling Procedures

The sample of the study comprised two B.Ed student cohorts at year levels three and four. The design did not require any sampling because the data obtained involved the entire cohort of hundred and twenty-two (n=122) year level four B.Ed respondents and the entire group of sixty-two (n=62) B.Ed year-level three respondents. At the end of the second semester, two sets of data were collected for each group. The respondents were registered for the B.Ed degree Senior and Further Education and Training (FET) phase. Upon graduation, they qualified as mathematics and physical science Senior and FET phase teachers. The first author assisted by a colleague collected the data from the two groups at the same time. The first author administered the questionnaire to year-level four students, while a colleague administered the questionnaire to year-level three students.

STUDY CONTEXT

The purpose of the B.Ed programme was to develop professionally qualified teachers to teach in the Senior and FET phases of the South African education system. The programme sought to equip the student teachers with relevant knowledge and teaching competences for teaching physical science and mathematics. At first and second years, the programme focused exclusively on teaching physical science (physics and chemistry), mathematics content knowledge and general pedagogy. At third and fourth years, student teachers did education Methods modules, which focused on developing students' pedagogical content knowledge for teaching natural science, physical science and mathematics. In the physical science education (Method) modules, students engaged in inquiry teaching practices, which sought to develop students' knowledge and skills in scientific inquiry – using mainly two inquiry frameworks: the Five E model of Instruction and a Conceptual Change Model of Instruction. While engaging in these inquiry models, student teachers learned to engage learners in: asking investigable questions, pose scientific problems, explore scientific phenomena, engage in conversations and arguments about the observed phenomenon, make sense of their observations and ask questions that arise from their observations. Students also got to understand how to listen to their learners' ideas and provide guidance to help them build and test their own explanations of the observed phenomenon.

During these last two years of the programme, year three students did six weeks of supervised practice teaching while at year four, they undertook a twelve-week supervised practice teaching in schools. During their time in schools the students were expected to take on teaching responsibilities, as well as also observe their mentors present lessons in their science classes. The year four, physical science Method modules focused strongly on developing the student teachers as reflective practitioners. Over and above presenting and observing their mentors teach, year four students also engaged in critical reflections on the lesson presented by their mentors as well on lessons they themselves presented. They were also expected to write assignments on their reflections of the different lessons they had presented as well as those presented by their mentors. The reflective activities were meant to begin when students were at school for a longer period of time at year level four.

DATA COLLECTION AND ANALYSIS INSTRUMENTS

The researchers used quantitative techniques to collect and analysis data. Two questionnaires were used to collect data: the Beliefs about Reformed Science Teaching and Learning (BARSTL) questionnaire was used to collect data on participants' science teaching and learning beliefs, while the Nature of Science as Argument Questionnaire (NSAAQ) was used to collect data on NOS beliefs. The BARSTL design is predicated on the notion that respondents with differing science teaching and learning beliefs will come up with different responses to statements expressing a perspective on science teaching and learning that is either reformed or traditional (Sampson, Enderle, and Grooms 2013). It contains 32 items organized into four subscales, each of which contains eight items. Four of these items are expressed in such a way that they represent a reformed view of science, while the other four represent a traditional view. Using a Likert-type response scale, science education students indicated how much they agreed or disagreed with each statement. Items representing a traditional view were graded in reverse. The total possible score varied from 32 to 128 points, with higher scores representing science teaching and learning beliefs that are compatible with reforms advocated by the current school curriculum (Sampson et al 2013). On the other hand, the NSAAQ was a five-point Likert scale, with a one viewpoint representing a naive NOS belief and the other representing a view of science as a process of explanation and argument (Sampson and Clark 2006).

DATA ANALYSIS

To find out if there were any significant differences between the two research samples, a t-test statistic was used. To find out if there was any statistically significant association between the students' NOS beliefs and their science teaching and learning beliefs, the Pearson product-moment correlation coefficient was used. Data were analysed using the SPSS 22 statistical package. The results were used to determine those students who held either naïve or sophisticated NOS views (Sampson and Clark 2006), and those who held either traditional or reformed science teaching and learning beliefs that are advocated by the current school curriculum reforms (Sampson et al 2013).

FINDINGS

To find out if there were any significant differences between the two research groups in (a) the student's overall mean NSAAQ scores and (b) the various NSAAQ subscales a t-test statistic was used. Levene's test for equality of variance was conducted, and the t-test results corresponding to equal variance and the four subscale scores were used to analyse the difference between the NOS beliefs at year level three and year level four. The study revealed (see Table1) that the overall mean score difference between the year three and year four science education student teachers' NOS beliefs was significant: [$t_0 = 4.192$, $p=0.000$, $df = 183$]. The mean scores indicated that student teachers' NOS beliefs were statistically significantly higher at year level four.

Table 1: Comparison of NOS beliefs mean scores with respect to study year levels

	Year-Three			Year-Four					
Scale	Mean	SD	N	Mean	SD	N	t_0	df	p-value
Overall	77.71	7.428	63	82.61	7.588	122	4.192	183	0.000*
Subscale1	16.67	3.162	63	16.55	3.035	122	0.246	183	0.806
Subscale2	17.40	3.160	63	19.69	3.173	122	4.662	183	0.000*
Subscale3	20.25	4.016	63	20.90	4.005	122	1.041	183	0.299
Subscale4	20.78	4.090	63	20.34	4.218	122	0.682	183	0.496

P<0.05*

When the NOS beliefs scores were analysed per subscale, the difference in year three and year four NOS beliefs scores was significant: [t_0 =4.662, p=0.000, df=183] for subscale 2. This shows that students at year-four level held superior NOS beliefs concerning how scientific knowledge is generated. However, the difference in mean scores of the two research samples in subscale1 (the nature of scientific knowledge), subscale 3 (what counts as reliable and valid scientific knowledge) and subscale 4 (the role scientist play in the generation of scientific knowledge), [t_0 = 0.246, p = 0.806, df = 183; t_0 = 1.041, p = 0.299, df = 183; and t_0 = 0.682, p = 0.496, df = 183, respectively] were not statistically significant. This suggests that year-four, science student teachers do not differ from year-three students in their NOS beliefs on the nature of scientific knowledge, what counts as reliable and valid scientific knowledge and the role scientists play in the generation of scientific knowledge.

Similarly, a t-test statistic was used to see if there were any statistically significant variations in year three and year four science education student teachers' teaching and learning beliefs mean scores and the various BARSTL subscales.

Table 2: A comparison of science teaching and learning beliefs mean scores of the two research samples with respect to study year levels

	Year level 3			Year level 4					
Scale	mean	SD	N	mean	SD	N	t_0- value	df	p-value
Overall	79.2	4.238	63	81.20	6.435	122	2.378	172	0.019*
Subscale 1	19.2	2,426	63	19.82	2.516	122	1.549	183	0.123
Subscale2	19.9	2.147	63	19.80	2.729	122	1.551	183	0.123
Subscale 3	20.0	2.433	63	21.57	2.412	122	2.564	183	0.011*
Subscale 4	20.0	1.316	63	19.95	2.787	122	0.478	182	0.633

p<0.05*

According to Table 2, a statistically significant difference in the overall mean scores existed between the two research samples regarding their science teaching and learning beliefs; [t_0 = 2.378, p = 0.019, df = 172]. This implies that year four student teachers had considerably more reformed-oriented science teaching and learning beliefs than year-three students. Further analysis of science student teachers' teaching and learning beliefs per subscale revealed that there was a significant difference in the mean scores of the two research samples on subscale 3 [t_0 = 2.564, p = 0.011, df = 183]. This implies that year-four students had considerably more reformed-oriented beliefs than year-three students on the characteristics of teachers and the learning environment. There were no significant differences between the two research samples regarding subscales 1 (how people learn about science), subscale 2 (learning design and implementation) and subscale 4 (the nature of the science curriculum), [t_0= 1.549, p = 0.123, df = 183; t_0=1.551, p = 0.123, df = 183; t_0= 0.478, p = 0.633, df = 182, respectively]. This suggests that respondents in the two research samples do not differ on the beliefs about how people learn about science, learning design and implementation, and the nature of the science curriculum.

The relationship between the student teachers' NOS beliefs and their science teaching and learning beliefs was investigated using the Pearson Product Moment correlation (r). The investigation sought to ascertain whether the relationship between respondents' NOS beliefs and their science teaching and learning beliefs was statistically significant at year level 3 as opposed to year level 4. As shown in Table 3, the correlation between year-3 respondents' NOS beliefs and science teaching and learning beliefs was not significant. However, for year-four respondents, there was a small but statistically significant correlation between NOS beliefs and science teaching and learning beliefs ($r = 0.290$, $p < 0.01$). This demonstrates that year level four science education student teachers' NOS beliefs were marginally related to their science teaching and learning beliefs. This modest relationship between these two variables shows that respondents who had superior NOS beliefs were more likely to hold superior science education and learning beliefs.

Table 3 Correlation matrix for science teaching and learning beliefs and the NOS beliefs scores (of year-three and year-four students)

Group	Scale	N	BARSTL	NSAAQ
Year Level 3	BARSTL	63	1 -	0.106 0.409
	2. NSAAQ		0.106 0.409	1
Year Level 4	1.BARSTL	122	1	0.290*
	2. NSAAQ		0.290*	1

*P<0.01

DISCUSSION AND IMPLICATIONS

This study focused on the student teachers' beliefs in their senior years of study. The study sought to determine whether science education student teachers held different beliefs in year-three from those in year-four of study. The study's major question was, "How do science student teachers' beliefs compare at different year levels of their studies?" This question sought to determine how year-three and year-four science education student teachers differed in their NOS beliefs and their science teaching and learning beliefs, as well as whether there was any correlation between science education student teachers' NOS beliefs and their science teaching and learning beliefs.

Research investigating the impact of teacher education programmes on student teachers' beliefs has found these programmes to be of major concern (Cheng et al. 2009). Al-Amoush et al. (2013, 476), for example, reported that "teacher education for both pre-service and in-service teachers did not seem to substantially change chemistry teachers' epistemological beliefs." Similarly, Lokollo et al (2019) came to the conclusion that, in general, chemistry student teachers held the same views about the NOS and technology, regardless of their seniority in the pre-service programme.

The student teachers whose beliefs the current study sought to understand went through the teacher education programme that sought to develop NOS and teaching and learning beliefs through inquiry pedagogies. As student teachers engaged in inquiry teaching and learning practices, they were expected to develop personal epistemologies of the nature of science as well as the broader beliefs of science teaching and learning practices. However, despite being involved in a yearlong programme aimed at supporting the development of NOS beliefs, year-three students were found to be naïve in all aspects of their NOS beliefs. This naivety could suggest that at this level, students are still worried more about engaging and developing knowledge and skills in inquiry practices than assigning meaning to those practices.

However, in their study involving 56 primary school science student teachers in Turkey, Kutluca and Aydın (2017, 637) found that "exposure to explicit NOS and socio-scientific argumentation processes had a significant influence on science student teachers' NOS understandings." Further, this study also revealed that year-four science education student teachers' NOS beliefs were superior to those of year-three students. In this regard, these results agree with those reported by (Cheng et al. 2009) who found that student teachers' personal epistemologies became more sophisticated towards graduation. In a similar vein, Lee et al. (2013) also reported that students at postgraduate level had more sophisticated personal epistemologies than students at undergraduate level. These findings showed that students at the exit level exhibited a stronger belief that knowledge is personally constructed (Chai et al 2006). Chai, Teo, and Lee (2010) attribute this relativistic stance shown by the senior students to teaching experiences in practicum as they play their new roles as teachers. Engagement in inquiry activities is considered to provide a learning context conducive to developing desired views of NOS (Schwartz, Lederman, and Crawford 2004).

In this study, students engaged in inquiry practices at both year three and year four levels. However, it was at year four that NOS beliefs were observed to be superior to those of year level three students. This improved level of sophistication could be attributed to the students' familiarity with the inquiry teaching and learning pedagogies. Moreover, year four level students' superior familiarity with inquiry practices could also be attributable to assigning meaning to the inquiry activities more than they did in year three. Furthermore, as the year four students started taking teaching responsibilities in schools for a longer period than in year three, they also started to critically engage in reflections on their lesson presentations and the lesson presented by their mentors. Individual students kept notes of their daily reflections and later wrote assignments on their teaching experiences during the whole duration of year four practice teaching practice. These year four reflection activities could have forced students to assign meaning in what they were doing instead of just focusing on presenting the lesson correctly as they may have done in year three where they were not expected to engage in these reflections. It is during these reflections that they may have developed different perspectives of the nature of science.

However, Vhurumuku (2015) contends that while student teachers' conceptions of scientific inquiry shapes their classroom behaviour and actions, students' behaviour and actions are also significantly influenced by school environment elements and the goal students set themselves to achieve from assessments.Vhurumuku (2015) discovered that school context elements such as having teaching and learning resource materials, having good supervision and assistance from mentoring teachers, and being surrounded by quality learners, influenced their behaviour and actions. Ramnarain and Hlatswayo (2018) however, contend that inquiry-based teaching and learning pedagogical practices are still a big challenge for many South African teachers. In this study, while student teachers spent a long time in schools during practice teaching in their final year, they were deprived of opportunities to design and present inquiry lessons and mentorship in inquiry pedagogies because of a lack of resources aligned with inquiry teaching in almost all the schools – as well as challenges that in-service teachers have with inquiry teaching and learning pedagogical practices. The resource-challenged schools also deprived student teachers of opportunities to reflect on inquiry-based lessons which could have helped them develop practice-based personal epistemologies. These serious weaknesses in the teaching and learning practices aligned with inquiry suggest that the time students spent in schools did not help them develop inquiry-related teaching practices which may have affected the development of their NOS beliefs. However, the results reported in this study contracted those earlier reported by Tarmo (2016) which revealed that student teachers maintained naive personal epistemologies even after attaining highest levels of education. In this study, the two groups had significantly different overall mean scores for science teaching and learning beliefs, with the year-four level students having a significantly higher mean score on science teaching and learning beliefs. This indicated that year-four respondents had more reformed-orientated beliefs about science teaching and learning than year-three respondents. The superiority of year four students' beliefs compared to those of year three on science teaching and learning suggests that as year four students were becoming familiar with inquiry-based teaching practices, they were possibly also assigning meaning to the inquiry teaching and learning activities that they engaged in. At the same time during this period, they had also started reflecting deeply about what it meant to be a science teacher. Further analysis of results showed that the mean score difference for the two research samples was significantly different for subscale 3. Year-four student teachers had a significantly high mean score than that of year- three student teachers on this subscale. This means that year-four students held more reformed science teaching and learning beliefs than year-three students, particularly on the teachers' characteristics and the learning environment. This suggests that on becoming familiar with inquiry teaching practices, year four students developed a better understanding of the characteristics of the science teacher that were aligned with inquiry teaching and the kind of an environment that needed to exist in their science classes if effective learning had to happen. Thus, the findings of this study are similar to those of Ozfidan et al. (2017) who also revealed that American teachers' beliefs were reformed orientated on the characteristics of teachers and the learning environment. Furthermore, both studies found that science students in both programmes graduated holding superior beliefs on the characteristics of science teachers and learning environment that must prevail in their science classes if they are to be effective science teachers. However, their superior understanding of the characteristics of science educators and their knowledge of the learning environment must manifest in how they create a responsive science classroom. For them to be competent science teachers, their developed beliefs must be complemented by beliefs of (a) how people learn about science, (b) lesson design and its implementation, and (c) the nature of the science curriculum. In these three areas of science teacher knowledge, year-four students, like year-three students, were found to hold traditional beliefs. This demonstrates that students graduate from the programme while they still hold traditional beliefs about some very important aspects regarding their teaching and learning practices. Again, this lack of development in these three categories of beliefs is not surprising considering that most students while in schools lacked support and mentorship in the designing, presentation and observation of inquiry lessons due to lack of resources for inquiry teaching in schools and their mentors' inability to mentor them on inquiry teaching practices. During these lesson presentations if students were properly supported and mentored, they could have developed reformed beliefs of how people learn science. For example if they had been given opportunities to engage in inquiry activities at school, they could have understood that: learners learn the most when they are able to test, discuss, and debate many possible answers during activities that involve social interaction, the science curriculum they implement requires them to encourage learners to learn and value alternative modes of investigations or problem solving and that during the lesson presentation, learners need to be given opportunities to test, debate and challenge ideas of their peers. Furthermore, lack of proper inquiry lessons in schools could have possibly deprived students of opportunities to develop science teaching and learning beliefs which they could have developed when reflecting on the lessons they had designed and presented as well as on the lesson presented by their mentors.

However, overall, the improvement in students NOS beliefs and their teaching and learning beliefs in year four could be attributed to the students' familiarity with inquiry teaching practices and the limited reflections on their teaching and learning practices and the teaching and learning practices of their mentors. However, the limited or mostly non-existent opportunities to reflect on inquiry lessons presented by their mentors and those presented by themselves and lack of proper mentorship on inquiry teaching and learning practices could explain why year-four students still hold positivist beliefs in many aspects of NOS and traditional beliefs as they exit the programme.

The study also found no significant correlation between year-three respondents' NOS beliefs and their science teaching and learning beliefs. This was however not in agreement with the previous research findings (Chan 2004; Yilmaz and Sahin 2011; Özdemir 2007) as it was expected that since year-three students were found to be naive in their NOS beliefs, their traditional science teaching and learning beliefs would correlate and be traditional.

However, in year-four, science education student teachers' NOS beliefs were found to be moderately positively related with science teaching and learning beliefs ($r=0.290$, $p<0.01$). This modest correlation between the two variables suggested that student teachers who held superior NOS beliefs were more likely to hold superior science teaching and learning beliefs. The study findings in this regard are consistent with other research findings. For example, Yilmaz and Sahin (2011) in their study, found the positive relationship between traditional beliefs and naive epistemological views, while constructivist practices were positively related with advanced epistemological beliefs. Furthermore, Özdemir (2007, 367) also found that teachers who hold naïve NOS beliefs "emphasize the product instead of the process of knowledge in their teaching'. They also emphasize the objectivity and reproducibility of science knowledge, which make their learners to conclude that everyone using the same experimental approach can reach the same truth about science knowledge. On the other, hand those who hold sophisticated beliefs, view learning as a constructive process that learners actively engage in to develop their own meaning through social interaction and to focus on students' interpretations rather than textbook interpretations. Literature therefore agrees with findings of this study on year-four respondents. The study however, contradicts the findings of Igwebuike and Oribhabor (2016) who found that the epistemological beliefs of pre-service biology teachers were not significantly influenced by students' year level of study.

The study findings that the students at year-three still hold naïve NOS beliefs and traditional science teaching and learning beliefs were not surprising if we consider that research (Richardson, Raths, and McAninch 2003; Bhattacharyya, Volk, and Lumpe 2009) has found that students who start teacher education programmes bring their strong beliefs about teaching and learning developed over many years from their schooling experiences into their teacher education programmes and sometimes hold on to them even after going through a teacher education programme. Again, this is not surprising given that at this stage of their learning year-three science student teachers are still dealing with the conflict between their strongly ingrained traditional ideas about science teaching (Dane 2010) and the new ideas that seek to promote reform-based practices in the programme.

The study findings have serious implications for the Bachelor of Education programme. According to Yılmaz-Tüzün and Topçu (2013) the development of student teachers' beliefs during their studies is crucial if they are going to be able to implement effective teaching and learning strategies that will develop their learners' appropriate knowledge and skills. This study has found that student teachers' NOS and teaching and learning beliefs at year three were naïve and traditional. It was only at year four where these beliefs improved and became sophisticated and reformed in some aspects of NOS and teaching and learning, However, overall, the study found that students exited the programme while still holding naïve and traditional beliefs in most aspects of the NOS and teaching and learning. These findings have very serious implications for the programme because they suggest that despite the student teachers' becoming used to inquiry practices and also improving in their beliefs, they however still exited the programme having not attained scientific literacy. According to Peffer and Ramezani (2019, 1) "achieving science literacy requires learning disciplinary knowledge, science practices, and development of sophisticated epistemological beliefs about the nature of science and science knowledge". This view suggest that for science education teachers to graduate from the teacher education programmes having attained scientific literacy, curriculum designers have to understand that NOS has become a critical component of scientific literacy and "a core educational objective of the school curriculum and teacher training programmes of many countries"(Lu, Zhang, and Wei 2018, 2). However, teacher education institution still depends a great deal on the kind of mentorship student teachers receive from in-service teachers during teaching practice for the development of their students sophisticated NOS and science teaching and learning beliefs. With most in-service science teachers' teaching orientations still firmly rooted in traditional teaching practices, student teachers are still going to be at the receiving end of poor mentorship that is not aligned with modern ways of teaching. It is for this reason that Nelson et al. (2019) are urging all those dealing with student teachers to foster their understanding of NOS by engaging them in activities that involve a deep reconceptualisation of the nature of science. By this reconceptualization of NOS (Nelson et al. 2019) seem to suggest that curriculum designers have to understand that the development of competent and scientifically literate science teachers is not only the responsibility of the teacher education institutions, but it is also the responsibility of the schools where student teachers are placed do practice teaching. These schools which are in partnership with teacher education institutions must also play a role in the development of competent and scientifically literate student teachers. However, for the schools to play their role effectively it is very important that in-service teachers be capacitated by teacher education institutions with knowledge and skills to enable them to assist student teachers under their care to develop sophisticated NOS and reformed teaching and learning beliefs. Nelson et al. (2019, 4) recommend that in capacitating the in-service science teachers, emphasis must be on them re-examining "their usual emphases on the steps of the scientific method and on scientific knowledge as largely true and then replace them with more realistic emphases on the degrees of uncertainty and the comparative basis of scientific knowledge." A similar call has also been made by Lu, Zhang, and Wei (2018) who concluded from their study in China that teacher education programmes should focus on shifting student teachers from strongly held traditional NOS views to embracing current NOS views.

This study also has serious implication for the Africanisation of higher education. Teacher education curriculum designers should understand that, how science student teachers present and interpret knowledge in their classes is largely influenced by their personal epistemologies. From the study findings these NOS beliefs seem to be at variance with the epistemology of science. The curriculum designers have to understand that to align the science student teachers' scientific epistemologies with the epistemology of science, the teacher education curriculum should foster philosophical and epistemological views of science that reflect the lived experiences of student teachers (Zorlu and Practice 2017). It is through this curriculum that student teachers will understand that people from various cultures (including African cultures) have contributed to the development of alternative ways of thinking that characterize the current mainstream science. Mudaly and Ismail (2013, 178) however, contend that South African science teachers still find it difficult to "teach culturally inclusive science" and to develop the cultural and social academic dimensions of natural science (Van Wyk 2002**).** Teachers still find it difficult to incorporate the values of their students' cultures into their science lessons (Abah, Mashebe, and Denuga 2015). According to Abah, Mashebe, and Denuga (2015, 570) cultural inclusive science can be achieved if there is a "proper integration of indigenous knowledge into science teaching activities". However, many teachers because they hold traditional beliefs about indigenous knowledge and even regard it as magic and removed from science (Onwu et al. 2006) fail to understand the point where the indigenous knowledge systems and scientific ways of knowing meet and influence each other. Teachers hold these traditional beliefs about indigenous knowledge even though there is a clear overlap between the nature of indigenous knowledge and the NOS (De Beer 2016) as the nature and structure of both knowledge systems are fundamentally alike and complementary (Abah, Mashebe, and Denuga 2015). It is this complementarity between these knowledge systems and their epistemologies that can be leveraged to develop science teachers' pedagogies that integrate indigenous knowledge with western knowledge and to deal with teachers' practices that always draw on the thought systems of western science (Mudaly and Ismail 2013).

Furthermore, alignment of student teachers' NOS beliefs with the epistemology of science is possible in a curriculum that encourages teaching and learning through "extensive hands-on activities, investigative laboratory activities, open-ended questions, inquiry-oriented discussion, cooperative learning, and the use of performance assessments as pedagogical tools" (Abah, Mashebe, and Denuga 2015, 3)

Teacher educators and teacher education curriculum designers should therefore understand that the teacher education curricular they design should assist science student teachers to achieve what (De Beer 2016, 48) refers to as "an epistemological border-crossing between western science and indigenous knowledge". As qualified science teachers and graduates from these curricular they will know that science teaching should "go beyond the current practice of transmission and indoctrination to facilitating subject matter learning through integration of the learner's Indigenous knowledge system" (Abah, Mashebe, and Denuga 2015, 2)

Through these curricular, science teacher education students will,

- "Get to understand that the historical, environmental, and cultural perspectives on science highlights how science changes over time and depends on people's lived social, religious, and political experiences".
- "Evaluate the limitations of the explanatory power of scientific models and of different theories to explain phenomena from their own perspective" (Department of Basic Education 2003, 11)

When students understand how science connects to their daily lives, their environment, and their future, they develop a broader NOS understanding (Department of Basic Education 2003).

CONCLUSION

This study found that year-four science education student teachers were more sophisticated in their NOS beliefs than year-three students. The same difference was also observed in respondents' science teaching and learning beliefs. At year level four, science education student teachers demonstrated that they have abandoned their naïve views of science knowledge as well their traditional teaching and learning beliefs which caused them to believe that the role of a teacher in a science class is to transfer knowledge to learners, to embracing a view that learners actively engage in knowledge construction activities to develop their science knowledge (Otting et al. 2010). The development of an understanding of the relations between NOS beliefs and their beliefs about science teaching and learning is very important in the South African education system context considering that teachers and mentors of these student teachers are products of an education system which required teachers to transmit to learner concepts which are precise and unambiguous. In these schools, teachers still use modes of instruction which require learners to receive knowledge instead of generating it. So, if these student teachers are exiting the programme with sophisticated and reformed beliefs, there is hope that when they start teaching, they will break this cycle of teaching using traditional methods in historically disadvantaged schools which is perpetuated by the naïve NOS beliefs and traditional teaching beliefs held by their mentors in schools.

The study was conducted in the inquiry-based teaching and learning environment. Teacher education will benefit from the findings of this study as it gives insight into the role inquiry teaching can possibly play in developing teachers' NOS beliefs and their science teaching and learning beliefs. The study clearly showed that student teachers demonstrated sophisticated NOS beliefs and reformed science teaching and learning beliefs at year level four than they did in year level three. The study concluded that the sophisticated NOS beliefs were possibly due to student teachers becoming familiar with inquiry practices in year-four. This familiarity with inquiry practices could have resulted in them developing NOS beliefs that are related and congruent to science teaching and learning beliefs. (Tsai 2002)_ENREF_59 calls these related and consistent belief systems nested epistemologies. (Tsai 2002, 777) contends that "nested epistemologies may influence how teachers perceive the implementation of science classes". However, teacher education providers should also know that the fact that student teachers still hold positivist beliefs about science in certain aspects of NOS and traditional beliefs in certain areas of pedagogical knowledge demonstrates that there are some aspects of teaching practices in the programme that still need to be changed to help student teachers develop sophisticated and reformed beliefs. (De Beer 2016; Cronje, De Beer, and Ankiewicz 2015) hold the view that the integration of the indigenous knowledge systems into the science teaching activities could possibly help develop sophisticated student teachers' personal NOS epistemologies. In line with this study findings, the development of these personal epistemologies could also lead to the development of student teachers' reformed science teaching and learning beliefs.

RECOMMENDATIONS

From this study findings it became clear that it is possible to design a programme that targets the development of science student teacher beliefs. Consequently this study avers that the development of student teachers beliefs should be the target of all science teacher education programmes if the ultimate goal of these programmes is to produce science teachers who are scientifically literate and capable of implementing effective teaching and learning strategies that will develop their learners' appropriate knowledge and skills Yılmaz-Tüzün and Topçu (2013). The study concluded that student teachers' beliefs could be developed in a programme that focuses on developing student teachers, competences in inquiry pedagogies and also engages them in teaching and learning reflection activities. However, the timing of these activities is very important. The study therefore recommends that teacher education programmes should provide the student teachers with opportunities to engage in reflections on the lesson presented by their fellow classmates (at the teacher training institution), their mentors (in schools) and by themselves (at both the teacher training institutions and schools). In their study Brownlee, Purdie, and Boulton-Lewis (2001) concluded that the teaching programme that encourages students to focus on reflection on epistemological beliefs, help students become more meta-metacognitive, while Bjønness and Knain (2018) confirmed that student teachers need to be given opportunities for reflections on personal experiences to increase their awareness of inquiry practices. However, the students should start engaging in these reflection activities very early in the programme. It is proposed that these reflections should start as early as year three instead of year four if the programme is to succeed in fostering the development of sophisticated and reformed NOS and science teaching and learning beliefs as the students exit the programme at the end of year four.

Furthermore, more studies need to be conducted to determine if the student teachers' superior beliefs as they exit the programme make them good science teachers. Since the students did Chemistry and Physics as majors in this programme to qualify as Physical Science teachers, further investigations need to be conducted to determine whether content knowledge had any role to play in the development of superior science student teachers' NOS beliefs and their science teaching and learning beliefs. This investigation will indicate whether superior NOS beliefs and science teaching and learning beliefs of student teachers in later stages of the programme are as a result of their great science content knowledge or other ecological factors.

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