African Journal of Teacher Education
ISSN 1916-7822. A Journal of Spread Corporation

Volume 13 No. 3 2024 Pages 52-85

Investigating the effect of subject specialisations, academic performance, and gender on pre-service teachers' nature of science beliefs

Nkosinathi Ngwenya

University of Zululand, South Africa

Abstract

The study sought to understand how students' subject specialisations, academic achievements and gender influence the belief about nature of science (NOS) they hold at the end of their four year Bachelor of Education (B.Ed) degree programme in South Africa. The study was underpinned by an epistemological development theory. It was a quantitative study which involved one hundred and seventeen fourth-year students registered for a four-year Bachelor of Education degree, of whom 72 were females and 45 were males. The study revealed the following: (i) Most fourth year pre-service students were neither naïve nor sophisticated in their conception of NOS beliefs when they exited the programme. Students NOS beliefs also differed with respect to whether they were female or males. Overall, female students were slightly more sophisticated in their NOS beliefs than their male counterparts. (ii) The study also revealed that specialising in Physical Science, Life Sciences, and Technology had no effect on NOS beliefs held by both male and female students. (iii) However, male students specialising in Mathematics were found to hold more sophisticated NOS beliefs and these beliefs were significantly superior to their female counterparts. (iv) Students who academically performed at a distinction level had significantly superior NOS beliefs than those whose academic performance was just at a pass level. (v) Female students specialising in Physical Science had superior beliefs about how scientific knowledge is generated.

Keywords: Academic achievement**;** epistemology; nature of science (NOS); pre-service teachers; science education; subject specialisation

Introduction

Research examining changes in pre-service teachers' NOS beliefs during the course of their preparation has increased in recent past (Chai, Khine, & Teo, 2006; Cheng, Chan, Tang, & Cheng, 2009; Yılmaz-Tüzün & Topçu, 2013; Bjønness & Knain, 2018)). Mansour (2009) posits that epistemological beliefs are personal theories that guide teachers’ practices. These beliefs also act as filters through which new messages concerning teaching and learning are reconciled with previously held information (Carter, 1990). Cheng et al. (2009) asserts that teachers’ beliefs shape their practical theories and their classroom practices. These beliefs may be held consciously or unconsciously and guide teaching practices (Alghamdi & Kim, 2019) and also impact student learning (Lumpe, Czerniak, Haney, & Beltyukova, 2012). Nespor (1987) contends that teachers rely on their core belief systems rather than on academic knowledge when determining classroom actions. Teachers’ beliefs have been found to influence the way teachers decide on their teaching objectives, lesson planning, and evaluation of learning in the classroom (Mahmood, 2007). Recently, Yilmaz and Sahin (2011), (Çam, 2015; Epler, 2011); Şen and Sarı (2017) have reported consistent results on the relationship between teachers’ beliefs and their teaching practices. For example, Çam (2015) has observed that pre-service teachers with advanced NOS beliefs use multiple student teaching methods including class discussions, peer teaching, collaborative groups, and also high-order questioning techniques in their science classes. Thus NOS beliefs affect whether teachers employ teacher centred or student centred instruction (Özdemir 2007).

Studies have found that NOS beliefs are central to science education because they decisively influence teachers’ classroom teaching practices. For instance, teachers who believe that science is an accumulation of knowledge tend to do experiments by following the textbook instructions and getting the right answers. In contrast, teachers who believe that science knowledge changes as observations or new compelling ideas come to light (Sampson & Clark, 2006) are more likely to encourage students’ discussions (Vázquez–Alonso, Manassero–Mas, García–Carmona, & Bennàssar-Roig, 2014). These studies have also found that individuals holding naïve understandings of NOS are inclined to treat scientific knowledge as certain and ignore the role of scientists' research background, their imagination and creativity, as well as other cultural and social factors in the scientific endeavours. In contrast, teachers with more sophisticated understanding of NOS are more likely to articulate the nature of scientific knowledge “as a social practice which involves cooperation, collaboration, and competition among scientist” (Sampson & Clark, 2006, p.7). These studies, therefore, agree with the suggestion that teachers’ belief systems are “valuable pre-requisite for better understanding of both teachers’ learning processes and their later actions in classroom settings” (Al-Amoush, Usak, Erdogan, Markic, & Eilks, 2013, p. 464). Yilmaz and Sahin (2011);Sampson and Benton (2006) emphasize that an appropriate understanding of teachers’ beliefs is required when initiating science education reforms as their successful implementation requires considerable adaptation of the teachers' beliefs to align with new teaching philosophies. Similarly, Kruss (2009) argues for the importance of teachers adapting their beliefs as they often are the ones expected to implement curriculum developed on epistemological principles that may contrast sharply with their own existing and accepted commitments and practices. It is therefore important to understand the relationship between the NOS beliefs that pre-service teachers hold and factors such as their subject specialisation, their academic abilities in those specialisations and their gender. Teacher educators also need to understand the kinds of epistemic beliefs that pre-service teachers are likely to hold when they exit the teacher education systemso that this understanding can be reflected in their programme design of teacher education programmes (Ferguson & Lunn Brownlee, 2018).

However, Abd-El-Khalick, Bell, and Lederman (1998) noted that the results of the increased research on pre- service and in-service teachers' understanding of the epistemology of science were mixed. Some found that science teachers do not seem to have an inadequate understanding of the nature of science and their views are not consistent with the contemporary conceptions of the NOS (Thye & Kwen, 2003; Adak & Bakır, 2017)**.** On the other hand, some research found that teachers have adequate understanding of NOS beliefs (Abd-El-Khalick et al., 1998). These contrasting views have instigated the need for more research for the understanding of teachers' beliefs. The current study thus also seeks to contribute to the debate by exploring the effect of subject specialisations, academic achievement, and gender on the development of pre-service teachers' NOS beliefs. The study was conducted at one of the rural universities in South Africa. The research participants were final-year students enrolled in a four-year Bachelor of Education (B.Ed) programme, with their subject specialisation in Science, Mathematics, Life Sciences and Technology.

Theoretical framework and literature review

Theoretical framework

Philosophers of science have described scientific epistemology as the nature of scientific knowledge, including the sources of such knowledge, its truth value, and scientifically appropriate warrants (Sandoval, 2005). However, to psychologists, personal epistemology refers to students' beliefs about the nature of knowledge and knowing (Borda et al., 2009). Hence, Abd-El-Khalick et al. (1998, p. 418), note that the Nature of Science (NOS) has been used to refer to the "epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge". Lederman (2006) has further characterised NOS as epistemological underpinnings of the activities of science and the characteristics of the resulting knowledge. Borda et al. (2009) argues that the term Nature of Science (NOS) is closely related to the philosophers' understanding of the term epistemology and is applied only to the realm of science. Cho, Lankford, and Wescott (2011) note that science educators describe epistemological beliefs as the Nature of Science (NOS), and these beliefs are context-specific to knowledge and knowing of science. However, Kutluca and Aydın (2017) hold the view that NOS focuses on social and cultural aspects of scientific knowledge while scientific epistemological beliefs are concerned with the justification of scientific knowledge. Mahler, Bock, and Bruckermann (2021), on the other hand, hold the view that NOS beliefs conceptually belong to teachers' epistemological beliefs relating to the nature of knowledge or of a particular science discipline. Like Cho et al. (2011), this study holds the view that epistemological beliefs are context specific and consequently refer to all epistemological beliefs which are context-specific about knowledge and knowing of science as the Nature of Science (NOS).

Studies of students' epistemological beliefs began with the work on intellectual and ethical development by Perry (Bodin & Winberg, 2012). His research laid a foundation for classifying students' epistemologies of science (Borda et al. 2009). Central to Perry's model is an emphasis on the changes that take place throughout childhood and adolescence about knowledge and learning. Perry proposed that students early on in their studies hold dualistic beliefs about knowledge; viewing knowledge as absolute and transferable. Later in their lives, they begin to hold more relativistic views and to acknowledge the context dependent nature of knowledge. This corresponds to a more sophisticated epistemology (Bodin & Winberg, 2012). Consequently, many studies by scholars with an interest in personal epistemology have been inspired by Perry's developmental models of epistemic cognition. They conceptualised epistemological beliefs as unidimensional. Paulsen and Wells (1998), for example, had their research based on the premise that personal epistemologies develop in parallel with individual cognitive development.

Following Perry's model, the next generation of researchers in personal epistemology viewed epistemology as a system of independent beliefs. Schommer (1989), a pioneer of this model, drew on the work of Perry in proposing a model of beliefs about knowing and learning that are more or less independent, rather than organised into positions or stages and maturing in synchrony (Hofer, 2001a). She identified four continuous structural dimensions and labeled them as stability, source of knowledge, ability, and speed of learning (Lunn Brownlee, Curtis, Spooner-Lane, & Feucht, 2017). Several research findings have confirmed the development of multidimensional epistemological beliefs. For example, Yilmaz-Tuzun and Topcu (2008) found that pre-service science teachers' epistemological beliefs developed independently and, as a consequence, they hold a range of epistemological beliefs that become more relativistic towards graduation. According to Demirbag and Bahcivan (2021, p. 259) in a "multidimensional perspective, people's epistemological beliefs expand on a naïve-sophisticated range".

In this study, NOS beliefs are conceived as context-sensitive and differ across subject domains and vary from being naïve to more mature (Aditomo, 2018; Guo, Hu, Marsh, & Pekrun, 2022). In this view, NOS beliefs can vary even among individuals with the same subject specialisation, individuals with similar academic performance and individuals of the same gender. NOS beliefs are also conceptualised as consisting of multiple independently operating dimensions (Chen, Morris, & Mansour, 2014). In this view, science teachers can believe, for example, that scientific knowledge comes predominantly from knowledgeable people, while at the same time they can also simultaneously believe that there can be multiple "right answers" to complex problems in science (Chen et al., 2014).

Literature Review

Studies focusing on the NOS indicate that disagreements exist among philosophers of science about what it is. This is not surprising given the multifaceted and complex nature of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Sandoval, 2005). These studies have mainly focused on pre-service teachers' conceptions of NOS and their translation into classroom practice (Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001). They have mainly found that participants' classroom practices were not aligned with their views about NOS and their science background, especially if teachers had not internalised the importance of teaching NOS. Palmquist and Finley (1997), for example, investigated the changes in NOS beliefs of students in a post graduate teacher education programme before and after the students embarked on a science teaching methods module. This mixed methods study found that before the students entered the teaching programme, they held a contemporary, i.e., postpositivist, view of scientific theory, knowledge, and the role of a scientist and a traditional, i.e., empiricist or positivist, view of scientific method. The authors also found that an index of students' contemporary views doubled, and the number of mixed views decreased by more than half after completing the Methods. These changes in NOS beliefs were observed even though there was no direct teaching of NOS beliefs during the module. Palmquist and Finley (1997) observed the positive changes in preservice teachers' NOS in classes where lecturers were using contemporary teaching strategies such as conceptual change and cooperative learning. In some studies, participants were found to possess adequate understanding of several important aspects of the NOS (Abd-El-Khalick et al., 1998).

NOS beliefs and subject specialisation

Studies focusing on the epistemology of science have investigated students' epistemological beliefs and their relationship to subject specialisations. These studies have found that subject matter shapes personal epistemology (Chai et al., 2006). Schommer-Aikins, Duell, and Barker (2003) studied general epistemological beliefs across domains and found that students' epistemological beliefs were similar for Mathematics and Social Sciences, as well as for Mathematics and Business Studies after students gained more academic experience in their domains of interest. This, however, was contrary to what they had observed for students' early levels of study where mathematics students demonstrated less competence in epistemological beliefs. Schommer-Aikins et al. (2003) concluded that this finding could be caused by the fact that as students gain deeper knowledge, they probably begin to see similarities at some more abstract level across domains. However, Dinal-Taganahan (2008); Marušić and Sliško (2012); and Stathopoulou & Vosniadou (2007b) have suggested that students develop mature beliefs in their subject specialisations as their subject knowledge evolves. For example, Dinal-Taganahan (2008) found that students develop mature beliefs about Physics as their knowledge of Physics grows and that holding mature beliefs about the subject facilitates the student learning of that subject. In the same breath, (Topcu, 2013) contends that individuals' epistemological beliefs may change when the discipline knowledge changes resulting in students with mature epistemology being able to acquire integrated understanding of science concepts. Bromme, Kienhues, and Stahl (2008), on the other hand, have found that gaining factual knowledge of different topics sometimes results in less sophisticated epistemological beliefs. Similar observations were also made by Stathopoulou and Vosniadou (2007a) when in their study found that a deeper understanding of Newtonian dynamics was from those students with naïve epistemological beliefs, while those with sophisticated epistemological beliefs were found to have a shallow understanding of Newtonian dynamics. This led Bromme et al. (2008, p. 11) to conclude that when individuals study a certain discipline, "their growing knowledge base may lead to the assumption that knowledge in the discipline is stable, secure and absolute, as the learner gets to the world of facts and well-established theories".

NOS Beliefs and academic achievement

There has been growth in interest in research in epistemological beliefs and academic achievement. Academic achievement or performance is the "extent to which a student, teacher or institution has achieved their educational goals (Dondofema, Mwenje, & Musemwa, 2020, p. 4).

Many studies have confirmed the existence of a positive relationship between epistemological beliefs and academic performance (Mohamed & El-Habbal, 2013; Topçu & Yılmaz-Tüzün, 2009; Vecaldo, 2017; Yılmaz-Tüzün & Topçu, 2013). Loewi (2007), for example, observed that epistemological beliefs are significantly more naïve in low than in high academically achieving students. Similarly, when Buehl and Alexander (2005)) examined the relationship between domain-specific epistemological beliefs within specific academic domains, they concluded that students with varying epistemological beliefs also vary with respect to their achievement. Similarly, Vecaldo (2017) found that pre-service teachers with mature epistemological beliefs had better academic performance than those with naïve beliefs. Mohamed and El-Habbal (2013), however, argue that it is difficult to reach a conclusion about the relationship between epistemic beliefs and academic performance as the literature has mixed results that makes it difficult to establish a linear one-way relationship. This view is also held by Topçu and Yılmaz-Tüzün (2009) who have argued that students' academic performance was affected by numerous factors.

NOS beliefs and Gender

The studies done on epistemological beliefs and gender have yielded very interesting results (Schommer-Aikins, Duell, & Hutter, 2005). For example, Lodewyk (2007, p. 324) found that boys "believed more naïvely than girls that one's ability is predetermined, that learning occurs quickly, and that knowledge is certain". Lodewyk (2007) concluded that these beliefs could handicap boys when engaging in learning and performance and may partially account for their low performance relative to girls on both tasks and their lower overall academic achievement.

Research on epistemological beliefs and gender has recently extended to teacher education (Arslantaş, 2015; Vecaldo, 2017; Yılmaz-Tüzün & Topçu, 2013). According to Bayraktar (2019), studies examining gender differences in epistemological beliefs have produced contradictory results. For example, Abedalaziz, Leng, and Song (2013); Arslantaş (2015); Dinç & Üztemur(2017) found that female student teachers held stronger epistemological beliefs than male student teachers whilst on the other hand Oskar, Tekkaya, Sungur, Cakiroglu, and Cakiroglu (2011) found that boys had more sophisticated epistemological beliefs than girls. Yenice (2015) found that female student teachers had much more developed and mature epistemological beliefs about science than male students. Yenice (2015) concluded that girls were ready to abandon representations of knowledge as certain and stable and embrace a relativistic view about knowledge when their content knowledge increases. These contrasting and different findings about the relationship between epistemological beliefs and subject specialisation's, academic achievement and gender have motivated this researcher to conduct this research to contribute to the ongoing debates and discussions pertaining to the issues that are investigated in this study.

Statement of the Problem

Although there is a significant increase in studies exploring relationships between epistemological beliefs and other educational variables (Yılmaz-Tüzün & Topçu, 2013), few empirical studies in the area of NOS beliefs have been carried out on subject specialisation, academic performance, and gender (Chai, Khine & Theo, 2006). This is the case in South Africa. First, there were not many studies focusing on the relationship among these constructs. Second, whilst studies exploring how pre service science teachers' epistemological beliefs about the nature of science differ based on their subject specialisations, academic performance and gender during various year levels of their study programmes may exist elsewhere, these studies have not explored whether these student teachers' NOS beliefs differ depending on their subject specialisation, their academic performance in their finals years of study. Nor have they explored whether the students are male or female as they exit the teacher education programme at the end of their final years of study. As noted by Vázquez–Alonso et al. (2014), research on teacher thinking on NOS is of interest for science education. This is the case in South Africa especially in historically disadvantaged schools where pre independence curriculum used to advocate only one view of the nature of knowledge, namely, that knowledge is absolute. Unfortunately, when learners view knowledge as absolute, "they think the source of knowledge is authority and thus resist any moves toward an epistemological position reflective of an evaluative view of science'' (Hand, Lawrence & Yore, 1997. p 1026). This historical curriculum problem is also compounded by the fact that women in the African cultural context were historically supposed to accept knowledge from authority without question (Schommer, 2003) and female learners as a result come to science classes holding this absolutist view about authority while male students believe themselves to be the authority and source of knowledge. Since the introduction of a new curriculum in South Africa marked a significant departure from the previous apartheid-era curriculum (Ramnarain & Padayachee 2015), the philosophical understanding of science should be given attention in teacher training to promote philosophical and epistemological views of science that accurately portray contemporary science (Zorlu, 2017; Hand, Lawrence & Yore,1997). This is necessary especially because post-independence, the NOS has been advocated as a critical educational outcome in South Africa (Lederman, 2006). Zorlu (2017) contends that NOS conceptualisations affect how a person will interpret content knowledge and the quality of socio scientific argumentation.

Palmquist and Finley (1997) posit that if teacher education programme designers accept the importance of understanding the nature of science, then they should accept that preservice science teacher education programmes are obligated to train teachers who understand a contemporary view of the nature of science and its applications to teaching. Vázquez–Alonso et al. (2014, p. 133) contend that knowing teachers' appropriate beliefs "could be educationally invaluable because they could serve as pedagogical hooks in teacher training and in the planning of a teaching STS-NOS curriculum". In the South African context, it is also important to determine which aspects of the nature of science pre-service teachers from historically disadvantaged background portray as they exit the programme at the end of four years of study. This is necessary so that if there are weaknesses in the teacher education programme pre-service teachers have gone through, curriculum may be adjusted accordingly.

The purpose of this study was to determine the NOS beliefs that pre-service science education teachers hold as they exit the teacher education programme at fourth year level and how these beliefs differ due to the students' subject specialisations, academic achievement, and gender.

The sub-questions are as follows:

a) What beliefs about the NOS do pre-service science teachers' hold as they exit the teacher education programme at year level four?

b) Do pre-service teachers' beliefs about the NOS differ based on subject specialisations and gender?

c) Do pre-service teachers' beliefs about the NOS differ based on their academic performance, and gender?

d) Do pre-service teachers' beliefs about NOS on each of the factor scores depend on gender, subject specialisations, and academic achievement?

Research Design

A cross- sectional design was chosen for this study due to its three distinctive features (De Vaus, 2007) that are relevant to the collection and analysis of data for this type study. The three distinctive features of the cross-sectional design are: a) no time dimension, b) reliance on existing differences and c) the nature of groups in the cross-sectional design. The features are discussed below.

a) No time dimensions

In the cross-sectional design, data are collected at one point in time (De Vaus (2007) to obtain an overall "picture" as it stands at the time (Kumar, 2011). This makes the cross-sectional design to differ from designs such as pre-test and post-tests designs or experimental designs where two sets of data on the same population are collected at different times to measure change in the phenomenon or assess the impact of an intervention (De Vaus, 2007). The cross-sectional design only measures the differences between groups rather than change(De Vaus, 2007)

b) Reliance on existing differences rather than change following intervention

The cross-sectional design collects data at one point in time and all analysis relies on differences in the sample at that point in time (De Vaus, 2007) whistles in the before and after design or an experimental design there is an active intervention by the researcher to produce change which is measured by comparing the difference in the phenomenon or variables before and after the intervention (Kumar, 2011). The cross–sectional design does not allow for differences to emerge over time. It relies on existing differences rather than examining the impact of experimental intervention (De Vaus, 2007).

c) The nature of groups in the cross- sectional design

In the cross- sectional design the groups are constructed on the basis of existing differences in the sample. "The sample is divided up into groups according to the category of the independent variable to which they happen to belong" (De Vaus, 2007, p. 172). This is unlike for example the experimental design which relies on comparing groups, where individuals have been randomly allocated prior to any experimental intervention to make the two groups identical (De Vaus, 2007). Thus, this study collected data at a particular point in time. The data were analysed by focusing on the existing differences between male and female students specialising in different subjects and had achieved different grades in their subject specialisations.

Sampling Procedures

The population for the study comprised of a cohort of Bachelor of Education (B.Ed) students at year level 4 of study. One hundred and seventeen (n=117, 72 females and 45 males) completed a Nature of Science as Argument (NSAAQ) questionnaire. The design did not require any sampling to be done as data collected involved the whole cohort of fourth year science education students. The data on students' beliefs about the nature of science were collected at the end of the second semester of the students' fourth year of study.

Context of the study

Students doing a Bachelor of Education (B.Ed) programme do their university's supervised school practicum for six weeks in their third year of study. In the fourth-year, students undertake school supervised practicum for two weeks before the start of university lectures where they present lessons under the supervision of the school-based mentors.

During the first two years of study students do the following compulsory subjects: Mathematics (48 credits), Physical Science [Chemistry (24 credits) and Physics (36 credits)], Technology (20 credits), and Life Sciences (12 credits). At third year level they do compulsory methodology subjects, Mathematics (in the Intermediate and Senior phase), Natural science and Technology (Intermediate phase), Natural Science (Senior phase) and Technology (Senior phase). At fourth year level students select two specialisations from the content subjects they did up to year level two as their majors to strengthen their content knowledge to teach at Senior phase level. The two specialisations do not carry the same credits and, as a result, the one which carries more credits is regarded as a major specialisation whilst the one with less credits is a minor specialisation. A major specialisation carries a total of 24 credits per semester which results in students earning a total of 48 credits in two semesters for a major specialisation. A minor specialisation is worth only 12 credits per semester, resulting in a student earning a total of 24 credits from a minor specialisation in two semesters. A student who chooses Mathematics as a major specialisation will graduate with a total of 84 credits in Mathematics including the 48 credits earned at year level one and year level two. Students who choose Physical Science earn a total of 108 credits [Physics (60 credits) and Chemistry (48 credits)]. Sixty credits are earned in Life Sciences if chosen as a major specialisation while a total of 64 credits are earned by the students for Technology if it is chosen as a measure specialisation.

Differences in students' beliefs about NOS could be due to different practices inherent in the different subject specialisations students choose or academic abilities in their subject specialisations or their gender. The study, therefore, sought to find out if pre-service teachers demonstrated any significant differences in their epistemological beliefs about NOS in their final year as a result of having studied content at a higher level in some subjects than in others and if their competences in their subject specialisations have caused them to think about science in a way that is different from those who did not demonstrate similar competences in their subject specialisation, and whether being males or females affected their epistemological beliefs in their specialisations and academic achievement.

Data Collection and Analysis Instruments

This study used quantitative data collection and analysis techniques. It utilised a Nature of Science as Argument Questionnaire (NSAAQ) for the data collection.

Questionnaire

The Nature of Science as Argument Questionnaire (NSAAQ) was used to collect data on the epistemological beliefs about the nature of science held by pre-service science education students. The NSAAQ is a five-point Likert scale designed such that one viewpoint represents a naïve epistemological belief about the nature of science while the other represents a viewpoint that is consistent with the view of science as a process of explanation and argument (Sampson & Clark, 2006). Students who hold naive understandings of NOS are inclined to treat scientific knowledge as certain, objective, representing one reality and as being a collection of facts about the world. They are inclined to believe that all science is based on a single scientific method. They are also inclined to believe that experiments prove ideas right or wrong, ignore the role of scientists' research background relating to imagination and creativity, as well as other cultural and social factors in science. In contrast, those with "informed" or "more sophisticated" understandings of NOS are inclined to believe that scientific knowledge describes what reality is like, and understand that scientific knowledge is tentative.

The NSAAQ has four subscales. In the first subscale the questions are about the nature of scientific knowledge. The second subscale is related to the methods that can be used to generate scientific knowledge. There are six questions in each of these scales. In the third subscale, there are seven questions on what counts as reliable and valid scientific knowledge, and the last subscale has seven questions addressing the social and culturally embedded nature of scientific practice.

Students' biographical data and academic performance were collected from academic records of students who participated in the first part of data collection. This data included students' specialisations, students' final year marks and students' gender. Permission to collect this data was granted by the university.

Data analysis

a) Descriptive statistics was used to determine the number of students who hold NSAAQ beliefs at various levels while Inferential statistics was used to determine whether subject specialisations, student academic achievement, gender and subject specialisations, gender and academic achievement had any significant effect on pre-service science teachers' beliefs about the Nature of Science as measured by the Nature of Science as Argument Questionnaire (NSAAQ) as follows.

b) A one-way between-groups analysis of variance (ANOVA) was used to explore the impact of:

   i. subject specialisation on pre-service teachers' NOS beliefs, and

   ii. academic performance on pre-service teachers' NOS beliefs.

c) Furthermore, a two- way ANOVA was used to determine the effect of:

   i. gender and subject specialisation on student teachers' NOS beliefs, and

   ii. gender and academic performances on student teachers' NOS beliefs.

   A two-way MANOVA was used to determine whether:

   i. gender and subject specialisation have any effect on each of the four factor scores of pre-service teachers' beliefs about the nature of science.

   ii. gender and academic performance have any effect on each of the four factor scores of pre- service teachers' beliefs about nature of science.

The SPSS version 28 statistical package was used to analyse data.

Ethical Consideration

Confidentiality, anonymity, and privacy were assured in that the participants' identities, as information sources, were not revealed to anyone and the information obtained from them was used only for the purpose of the study.

Finding

The NSAAQ scores ranged from 1 to 130. To determine pre-service science teachers' conceptions of beliefs about the Nature of Science (NOS), scores were divided into three levels. Level 1 scores range from 1- 43, Level 2 scores range from 44-87 and Level 3 range from 88-130. These scores were obtained by dividing the possible maximum score a candidate could get into three levels. Level 1 represents a score of up to a third NOS questions answered correctly. Level 2 represents a score between one third and two third of NOS questions answered correctly, and level 3 represents a score obtained by answering correctly more than two third of the NOS beliefs questions. This categorisation of epistemological beliefs is based on the one used by Borda et al. (2009); Carey, Evans, Honda, Jay, and Unger (1989); Smith and Wenk (2006). According to Smith and Wenk (2006), at level 1 candidates make no differentiation between scientists' ideas, activities, or experimental results and as a result they lack appreciation of the role of scientists' ideas in guiding their activities. Students whose scores were at level 1 were considered naïve. Smith and Wenk (2006) regard candidates at level 2 as people who "make a clear differentiation between the ideas scientists are developing about the world and their experimental results or data that they have collected in the service of testing or evaluating those ideas. They also see scientists as designing experiments, using careful measurements, or making observations in the service of testing their initial ideas" (2006, p. 4). According to Dorsah (2020) students at level 2 hold transitional views of NOS. These ideas represent students who are neither naïve nor sophisticated in their conception of NOS beliefs. The transitional views reflect a transition by the pre-service teachers from naïve to sophisticated views of NOS. Candidates at Level 3 are considered sophisticated in their NOS beliefs. According to (Sampson & Clark, 2006, pp. 4-7), these students view science as a process of explanation and of mastery of the skills of scientific argument and they understand that:

a) Scientific knowledge varies in its scope, purpose, and degree of certainty and that the overall purpose of science is to develop an increasingly better understanding of how things work in the world.

b) A diversity of scientific methods exists to properly understand science as a process of explanation and argument, and that the methods used to generate scientific knowledge are diverse. There is no fix set of steps that scientists always follow that define how scientific knowledge is generated.

c) What counts as reliable and warranted scientific knowledge makes science unique from other ways of knowing and that in science, testing, improving, and discarding of theories, whether old or new, go on all the time.

d) Science is a social and cultural practice and it is people that construct scientific knowledge.

e) Scientific knowledge is constructed, and creativity plays an important role in the development of scientific knowledge because human creativity is the source ofnew and innovative ideas.

The overall NSAAQ score, given in table 1, shows that out of 117 students, zero students obtained a score ranging from1-43, 80 (68.4%) obtained scores from 44-87, and 37 (31.6%) obtained scores ranging from 88-130. This suggests that most pre-service students exited the programme holding NOS beliefs that were neither naïve nor sophisticated (Level 2). The same picture is observed when students NOS beliefs were analysed according to subject specialisations. In all the subject specialisations, most students were found to hold beliefs at Level 2 and scores according to gender show that 48 (41.0%) female students held beliefs at level 2 as opposed to 32 (27.4%) male students, and 24 (20.5%) female students were at level 3 whilst only 13 (11.1%) males were at the same level.

Furthermore, the overall NSAAQ mean scores show that the female students' mean score was 84.01 with a standard deviation of 7.650 while the mean score for males was 83.51 with a standard deviation of 7.127. Overall, female students were found to hold slightly superior beliefs than their male counterparts. With respect to subject specialisations, the mean score for male Mathematics students was 88.07 with a standard deviation of 7.815 while the female Mathematics students score was 81.20 with a standard deviation of 5.167. This mean score suggests that male students doing Mathematics hold sophisticated NOS beliefs which are also superior to their female counterparts. For all other subjects, the mean scores differed slightly between male and female pre- service science teachers.

Students' academic performance was classified using the university academic performance classification system. Students who score from 50 to 64 are classified as having obtained a Pass; those who obtain a mark from 65 to 74 as having passed with Merit, while those who obtain a mark from 75 to 100 are classified as having passed with Distinction. 32 (27.3%) students in the 50-64 category were at level 2, and 10 (8.5%) were at level 3. In the 65-74 category, 45 (38.5%) were at level 2 and 17 (14.5%) were at level 3, whilst in the 75 and above category, 6 (5.1%) were at level 2 and 7(6.0%) were at level 3. These results show that most students in the 75 and above category hold superior beliefs compared to students in other categories. In the 75 and above category, female students have a mean score of 89.33 with a standard deviation of 6.532, and male students have a mean score of 88.06 with a standard deviation 6.149. These mean scores show the superiority of NOS beliefs for both female and male students in this category with female students having slightly more superior NOS beliefs than their male counterparts.

Exploring the effect of subject specialisation and academic performance on NOS beliefs

A one-way between-groups analysis of variance (ANOVA) was conducted to explore the impact of subject specialisation on pre-service teachers' NOS beliefs. ANOVA reflects all possible differences between the means of the groups analyzed (Abdi & Williams, 2010). One-way analysis of variance involves one independent variable which has a number of different levels (Pallant, 2020). Participants were divided into four groups according to their subject specialisations (Physical science, Life science, Mathematics and Technology). The mean NOS beliefs scores for the four specialisations Physical science (M=85.70 and SD=6.308), Life science, (M=83.75, SD=7.734), Mathematics, (M=84.73, SD=7.254) and Technology, M=82.65, SD=7,088 were not statistically significantly different at the $p < .05$ level. A one-way between-groups analysis of variance (ANOVA) was conducted to explore the impact of academic performance on pre-service teachers' NOS beliefs. Participants were divided into three groups according to the system used by the university to categorise students' academic performance, with students scoring marks from 50% to 64% categorised as having just achieved a Pass, those scoring from 65% to 74% categorised as having passed with Merit and those who have scored from 75% to 100% categorised as having passed with Distinction.

There was a statistically significant difference at the $p < .05$ level in NOS beliefs scores for the three groups: F (2, 114) = 3.86, p = .024. Despite reaching statistical significance, the actual difference in mean scores between the groups was quite small. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for 50 to 64 group (M = 82.17, SD = 8.076) was significantly different from the 75 to 100 group (M = 88.54, SD = 6.105). The 65 to74 group (M = 83.95, SD= 6.860) did not differ significantly from either 50 to 64 or 75 to 100 groups. This suggests that students with high academic achievement have significantly superior NOS beliefs compared to those in lower categories.

Exploring the effect of gender, subject specialisation and academic performance on NOS beliefs

A two-way between-groups analysis of variance (ANOVA) was conducted to determine whether gender and subject specialisations, gender and academic achievement had any significant effect on pre-service science teachers' beliefs about the Nature of Science as measured by the Nature of Science as Argument Questionnaire (NSAAQ) questionnaire. According to Pallant and Manual (2011, p. 265) "Two-way means that there are two independent variables, and between-groups indicates that different people are in each of the groups". To test the effect of subject specialisation and gender on NOS beliefs, male and female participants were divided into four groups according to their subject specialisations, namely Physical science, Life science, Mathematics and Technology. On conducting the Leven's test of variance, the value was found to be (0.99). This value is larger than .05 which suggests that the homogeneity of variances assumption was not violated. On analysing the result, a significant interaction effect between gender and subject specialisation F (3, 117) = 2.704, p = .049 with the effect size (partial eta squared =.069) was found. This indicates that subject specialisation has an effect on beliefs about the nature of science for males and females. Male students specialising in Mathematics had a significantly higher mean score (M=88.07, SD=7.185) than females (M=81.20, SD=5.167). There was no significant effect for gender F (1, 117) =1.66, p= .20. There was also no main effect for subject specialisation F (3,117) =.93, p= .43.

For the impact of gender and academic performance on pre-service teachers' beliefs about the nature of science, male and female participants were divided into three groups according to the system used by the university to categorise students' academic performance, with those scoring marks from 50% to 64% categorised as having just achieved a Pass, those scoring from 65% to 74% categorised as having passed with Merit and those who have scored from 75% to 100% categorised as having passed with Distinction. There was no significant interaction effect between gender and academic performance on pre-service teachers' beliefs about the nature of science F (2, 117) = .06, p = .94.

Table 1 NOS score levels per subject and gender

Levels	**N**	**Phy/Sci (N)**	**Life/Sci(N)**	**Maths (N)**	**Tech (N)**	**Male(N)**	**Female(N)**
1-43	0	0	0	0	0	0	0
44-87	80(68.4%)	6	54	5	15	32(27.4%)	48(41.0%)
88-130	37(31.6%)	4	22	6	5	13(11.1%)	24(20.50%)

Total	**117(100%)**	**10**	**76**	**11**	**20**	**45**	**72**

Table 2 Participants NOS score levels against their academic performance and gender.

Participants	**Performance Category**	**NOS score Levels**	**N (%)**	**Mean score**	**Std deviation**
	50-65		42(35.9%)	82.17	8.076
		44-87	32(27.3%)		
		88-130	10(8.5%)		
	65-75		62(53%)	83.95	6.860
		44-87	45(38.5%		
		88-130	17(14.5%)		
	75 and above		13(11.1%)	88.54	6.105
		44-87	6(5.1%)		
		88-130	7(6.0%)		
	Total		**117(100%)**	83.82	7.426
Male	50-65		14(12.0%)	81.14	6.395
		44-87	9		
		88-130	5		
	65-75		24(20.5%)	83.62	7.418
		44-87	17		
		88-130	09		
	75 and above		07(6.0%)	88.06	6.149
		44-87	3		
		88-130	4		
	Total		**45(38.5%)**	83.51	7.127
Female	50-65		28 (23.9%)	82.68	8.861
		44-87	17		

		88-130	11		
	65-75		38(32.5%)	84.16	6.578
		44-87	25		
		88-130	13		
	75 and above		06(5.1%)	89.33	6.532
		44-87	2		
		88-130	4		
	Total		**72(61.5%)**	84.01	7.950

Exploring the effect of gender, subject specialisation, and academic performance on factor scores of pre-service teachers' NOS beliefs

To explain the effect of gender, subject specialisation, and academic performance on each of the four factor scores of pre-service teachers' epistemological beliefs about the nature of science, the following were used:

(NSAAQ) scale

a) What the nature of scientific knowledge is,

b) How scientific knowledge is generated,

c) What counts as reliable and valid scientific knowledge and

d) The role played by Scientists in the generation of scientific knowledge

a Multivariate analysis of variance (MANOVA)

MANOVA is a method that simultaneously assesses more than a single outcome variable and is used to control errors resulting from multiple comparisons (Yılmaz-Tüzün & Topçu, 2013).

To test the MANOVA on NSAAQ scale assumptions, the normal distribution was tested with the univariate and multivariate test of normality. The Kolmogorov-Smirnov statistic was found to be below 05, suggesting non-normality distribution in all the four subscales. The Mahalanobis distance was 19.475 suggesting the existence of outliers as this value is greater than the critical value for four dependent variables. To deal with the outliers, subscale 4 was removed and a new value of Mahalanobis distance of 14.993 for the three subscales (1, 2 and

3) less than the critical value was obtained. The Box Plots results (Box's M significance value = 0.297) suggested that the covariance matrices and error of the dependent variables were equal across groups (Pallant, 2020). Multicollinearity was tested and the Tolerance and VIF values were found to be greater than 0.1 and less than 10 respectively. A linear assumption was checked. According to Pallant (2020), linearity refers to the presence of a straight-line relationship between each pair of dependent variables. For each pair of dependent variables, the scatterplots were checked, and a linear relationship existed instead of curvilinear or diagonal relationships.

A 2 by 3 MANOVA was run to determine the possible difference between pre-service male and female science teachers and their subject specialisations and between pre- service male and female science teachers and their academic performance on the three factor scores of beliefs about the nature of science.

The multivariate test had a significant interaction effect for gender and subject specialisations; Roy's Largest Root =.083, F (3.030), p= .032; Partial Eta Squared= .077. When the results for the dependent variables were considered separately, the only difference to reach statistical significance was subscale 2 (How scientific knowledge is generated); F (3.117) = 2.967 p= .035, Partial Eta Squared= .075. This indicates that subject specialisation has an effect on NOS beliefs about how scientific knowledge is generated for males and females. Female students specialising in Physical science had a significantly higher mean score (M=23.25, SD=.975 than males (M=20.33, SD=2.338).

The multivariate test had no significant interaction effect for gender and academic achievement; Pillai's Trace =.095, F (1.832), p=094; Partial Eta Squared= .048. There was also no significant main effect for gender; Pillai's Trace =.019, F (.688) = p.561, Partial Eta Squared=.019, and no significant main effect for academic achievement: Pillai's Trace =.037, F (.684) = p.663; Partial Eta Squared= .013.

Discussion and implications

This study sought to understand whether the NOS beliefs that science education students hold as they exit the four-year science teacher education programme depended on subject specialisations, academic performance and gender. Studies examining gender differences in NOS beliefs have produced contradictory results (Bayraktar, 2019). In this study, both male and female students were found to hold NOS beliefs at Level 2 and Level 3 only as they exited the B.Ed programme. There were no students who were found to hold NOS beliefs at level 1, categorised in this study as naïve. This study contradicts existing research findings which according to Borda et al. (2009) have consistently shown that undergraduates hold, and sometimes leave teacher education programmes with, naïve epistemologies. For example, Dorsah (2020) in a similar study in Ghana found that pre-service science education teachers did not have adequate conceptions about nature of science. Furthermore, in another similar study conducted in Turkey, Dogan and Abd-El-Khalick (2008) found that the majority of teachers held naive views of the NOS beliefs which were mostly similar to those of their students. In this study, while candidates were not completely naïve, they were also not sophisticated in their NOS beliefs. Instead, they were found to be moving away from naivety in their beliefs and on their way to embracing sophisticated NOS beliefs. Dorsah (2020) calls these NOS beliefs *transitional views of NOS* as they reflect a transition by the pre-service teachers from naïve to sophisticated views of NOS. For example, when students were called upon to decide whether they considered science knowledge to be objective or subjective, most of took a neutral position suggesting that they agree with neither of the two statements. This lack of decision is a sign that most of them have moved from the naïve level but have not reached sophistication in their NOS beliefs.

These findings show that students graduating from the programme have not moved completely away from holding absolutist views about science. These are pre independence views that the programme has sought to deal with. Female students were slightly more sophisticated in their nature of science beliefs than male students. However, this difference between male and female students was not significant.

A comparison between female and male students NOS beliefs and their subject specialisations revealed that female and male students specialising in Physical science, Life sciences, and Technology held NOS beliefs at level 2 when they exited the programme which suggested that students doing these subject specialisations were not able to make a clear differentiation between the ideas scientists are developing about the world and their experimental results or data that they have collected in the service of testing or evaluating those ideas This aligns with Bromme et al. (2008) as well as Thye and Kwan (2003) who found that gaining factual knowledge on different topics sometimes results in less sophisticated epistemological beliefs. It, however, contradicts Dinal-Taganahan (2008) who found that students develop mature beliefs about Physics as their knowledge of Physics grows. Physical Science, Life Science and Technology specialisations also had no effect on NOS beliefs held by male and female students. However, male students specialising in Mathematics were found to hold more sophisticated NOS beliefs and these beliefs were significantly superior to their female counterparts. This finding was completely unexpected because students doing Physical Science, Life Science and Technology students were expected to hold more sophisticated beliefs than those doing Mathematics because the beliefs being investigated are in the domain of science. Moreover, according to the NOS literature, students hold naïve domain specific epistemological beliefs when they specialise in pure and hard science subjects and sophisticated domain specific epistemological beliefs when they specialise in pure and soft science subjects.

In line with the existing research literature, the expectation would therefore have been that student teachers studying pure and hard science subjects would hold naïve NOS beliefs in all these subjects. According to Chai, Teo, and Lee (2010); Paulsen and Wells (1998); Schommer-Aikins et al. (2003), while studying pure and hard science subjects, students learn that consensus is what characterises knowledge building practices in those subjects. Schommer-Aikins et al. (2003, p. 352) argue that practices in these fields of study are "characterized by engagement that leads to an agreement on a single paradigm that allowed scholars within the discipline to agree on research methodology, basic concepts, and research questions". Aditomo (2018, p. 4) further argues that "in hard disciplines, there are standard experimental paradigms, measurements, and ways of interpreting data, rendering knowledge as more objective than in soft disciplines, where the definitions and ways of observing core phenomena are sometimes contested". Mathematics is one of the pure and hard subjects. The results are more surprising because Mathematics is considered by many students as a discipline with certainty and often has only one right answer (Topcu, 2013). To try and make sense of this finding, it is important to look at the curriculum for this programme. The level at which the pure and hard specialisation content is dealt with in year levels 1, 2, and 4 in a programme where teachers are being prepared to be specialists of Mathematics at intermediate and senior phase could be lacking the rigour that characterises the pure and hard Mathematics content taught to students who will teach at high school levels. The level at which the Mathematics content for teachers at the intermediate and senior phase is pitched could possibly be at a level where it is applied or used to explain issues related to the teaching and learning of Mathematics in schools. In that case, according to Schommer-Aikins et al. (2003), it is considered as being used as an applied subject. Applied subjects are about the business of using knowledge (Schommer-Aikins et al., 2003). According to (Schommer-Aikins et al., 2003, p. 352), soft or applied subjects "embrace diversity of opinion and encourage students to play with ideas and stand toe-to toe with ambiguity". In the programme, teachers do Methods of Mathematics and Methods of other science domains as compulsory subjects in the Method year. So, a combination of the ideas from the science domain and the ideas from the mathematics domain may have resulted in the ideas of a Mathematics teacher being stronger than ideas from the other subjects.

Regarding the superiority of NOS beliefs in Mathematics for male students over those of females, this study findings contradict Hofer (2001b) who argues that men favour a separate mode of learning which is privileged by an academic environment which results in women more likely to favour a ‘‘connected’’ approach to knowing and consequently leads to holding superior beliefs. These results could also show that mathematics practices still favour men and men find it easy to relate with issues discussed in mathematics and examples used in these discussions are still in the contexts that men are familiar with especially because mathematics is still largely taught by men both in schools and at teacher training institutions in South Africa.

This study found that Academic performance influenced the development of pre-service teachers' NOS beliefs. Students who academically performed at a distinction level had significantly superior NOS beliefs than those whose academic performance was just at a pass level. This suggests that as the students develop a deeper knowledge of the subject, they also begin to see connection between NOS and science knowledge. This is in line with the observations by Mohamed and El-Habbal (2013); Topçu and Yılmaz-Tüzün (2009); Yılmaz-Tüzün and Topçu (2013) that pre-service science teachers' epistemological beliefs have a relationship with their academic achievement. They found that high achiever pre-service science teachers believed that knowledge about scientific concepts is ever changing, and that this understanding is complex rather than simple. Similarly, in the current study high achievers were found to believe that scientific knowledge represents only one possible explanation or description of reality, and that scientific knowledge usually changes over time as the result of new research and new perspectives. The study also found that academic performance between genders had no effect on pre-service teachers' NOS beliefs. This study finding is similar to the findings by Conley, Pintrich, Vekiri, and Harrison (2004) who in a study conducted in America found no significant interactions between gender and achievement on any of the four epistemological belief measures.

Regarding whether the difference between pre-service teachers' beliefs about NOS factor score depended on gender, subject specialisations, and academic achievement, the study found that subject specialisation influenced NOS beliefs about how scientific knowledge is generated for male and female students. This is the same as found by Ngwenya and Imenda (in press) that students at fourth year demonstrated growth only in the methods that are used to generate scientific knowledge in science. However, in the current study, female students specialising in Physical science had significantly superior beliefs about how scientific knowledge is generated. The fact that it is science students who developed superior beliefs about how science knowledge is generated is not surprising as they have over a period of four years, especially during Method year, been exposed to real practices of generating and constructing science knowledge. This observation is supported by Palmquist and Finley (1997) who argue that when student teachers who have a background studying and working in the science fields, and have been introduced to some of the philosophical concepts of science come across the nature of science and the nature of science teaching, they are able to contemplate the implicit relationships between science and NOS more deeply than if they had no prior conception. Furthermore, the fact that only one subscale out of the three developed for both male and female students shows the complexity of NOS beliefs and also supports the multidimensional nature of epistemological beliefs, as well as the view that beliefs do not develop at the same time. However, why female students hold superior NOS beliefs than male students require further explanation. According to Linn and Hyde (1989), gender differences are not general but specific to cultural and situational contexts. Since scientific practices are characterised by community debates and discussions that are context specific, it is possible that the female students find it easy to relate with these scientific practices because they resonate with their everyday practices.

Conclusion, Recommendations, and Implications

Fishbein and Ajzen (1975) and Luft and Roehrig (2007) contend that beliefs are personal constructions and entities that belong to an individual and are formed because of an individual's direct experience with an object. In this study, students had four years of direct experience with teacher education practitioners in teacher training as well as with subject mentors in schools during teaching practice. Following these four years of active interaction between students and all the relevant stakeholders, this study sought to explore whether pre-service science education students' NOS beliefs are influenced by their subject specialisations, their academic performance, and their gender as they exit the teacher education science education programme. Understanding the students' NOS beliefs as they exit the teacher education programme is very important for this study because, as Luft and Roehrig (2007) suggest, if teacher education programmes are to support the ongoing development of science teachers and influence their classroom teaching practices, teacher education programmes ought to focus on the development of preservice science teachers NOS beliefs. In this study, most students exited the teacher education programme with NOS beliefs that suggest that they were in transition from being naïve to being sophisticated in their NOS beliefs. This finding suggests that students are neither naïve nor sophisticated in their NOS beliefs as they exist the programme. This poor development of NOS beliefs has been attributed to poor mentorship on inquiry-based teaching that students receive during practice teaching (Ngwenya and Imenda in press), which deprives students of opportunities to reflect on their practices and develop sophisticated beliefs.

The study has also found that students' NOS beliefs are influenced by the subject specialisations, their academic performance and gender, as male students doing Mathematics as well as students performing at distinction level were found to hold superior beliefs. These findings are very encouraging as they show that students who are doing certain subjects, and those who attain a certain pass mark in their academic performance exit the programme at fourth-year level with sophisticated NOS beliefs. This sophistication suggests that students have shifted away from portraying the world as a set of absolutes characterised by right and wrong answers (Osborne, Erdura, Simon, & Monk, 2001). Furthermore, both male and female students were found to have developed a sophisticated view about the role played by scientists in the generation of science knowledge with the female students demonstrating a significantly superior view than their male counter parts. In line with this finding, this study recommends that since existing research suggests that gender differences are a function of cultural contexts and situation (Linn & Hyde, 1989), African students must be encouraged to participate in many social activities (like stokvels) where they engage in debates and reach consensus, agreements through dialogue on, for example, the saving model to be followed and how much will be contributed when following this model. During these activities, consensus is reached through dialogue; this may align with science practices. These practices need to be identified and investigated in communities to determine the extent to which students who participate in them develop sophisticated NOS beliefs. Investigations should be conducted in communities where these practices are done by everyone, irrespective of whether they are male or female, to determine whether they would favour the development of NOS beliefs of a particular gender in science teacher education programmes. Since the study also revealed that students who have superior content knowledge also have superior beliefs about NOS, there is a need to investigate whether all the students with superior beliefs become good teachers when they start teaching. Lastly, more research must be done to investigate the teaching pedagogies and strategies that can assist in increasing the number of students who achieve at a distinction level in the programmes that science teachers go through.

The findings of this study have serious implications for how South Africa's teachers teach when they start their career as science teachers. Since these teachers were expected to graduate from the programme with sophisticated and constructivist beliefs, the traditional and positivists beliefs that they have not fully abandoned as they graduate from the programme suggest that they are likely to go back to the field as science teachers who still engage learners in teacher-centred teaching methodologies characterised by lack of focus on material-based teaching and with traditional assessment practices where lower order questions dominate. This unfortunately suggests that the programme has failed to break the vicious cycle where teachers of different generations continue to graduate with the low level of NOS beliefs. This is untenable because the expectation was that most students would graduate with sophisticated beliefs that suggest they have moved away from the pre-democracy curriculum practices that their teachers went through which led them to develop as uncritical implementers of the curriculum. Nonetheless, there are positives from the findings of this study that the programme designers can derive. The fact that there were students doing certain subject specialisations who obtained a mark at distinction level demonstrates that all students can still attain sophistication in their NOS beliefs. For this to happen, facilitators in teacher education programmes must work harder to make sure that the number of students who achieve high marks increase in their subject specialisations. Also, the findings suggest that many more students should be encouraged to take subjects such as Mathematics in these teacher education programmes if more students are to develop sophisticated NOS beliefs.

References

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science education, 82*(4), 417-436.

Abdi, H., & Williams, L. J. (2010). Contrast analysis. *Encyclopedia of research design, 1*, 243-251.

Abedalaziz, N., Leng, C. H., & Song, J. (2013). Epistemological beliefs about science in Malaysian context. *Life Science Journal, 10*(2), 2959-2966.

Adak, F., & Bakır, S. (2017). Science teachers and pre-service science teachers' scientific epistemological beliefs and opinions on the nature of science. *Cukurova University Faculty of Education Journal, 46*(1), 134-164.

Aditomo, A. (2018). Epistemic beliefs and academic performance across soft and hard disciplines in the first year of college. *Journal of further and Higher Education, 42*(4), 482-496.

Al-Amoush, S., Usak, M., Erdogan, M., Markic, S., & Eilks, I. (2013). Pre-service and in-service teachers' beliefs about teaching and learning chemistry in Turkey. *European Journal of Teacher Education, 36*(4), 464-479.

Alghamdi, A. K. H., & Kim, S. Y. (2019). The impact of a science methods course on female pre-service teachers' beliefs within a Saudi-Arabian context. *Journal of Baltic Science Education, 18*(1), 19-38.

Arslantaş, H. A. (2015). Epistemological beliefs and academic achievement. *Journal of Education and Training Studies, 4*(1), 215-220.

Bayraktar, S. (2019). Pre-service primary school teachers' scientific epistemological beliefs and attitudes toward science: Is there a relationship? *World Journal of Education, 9*(6), 83-97.

Bjønness, B., & Knain, E. (2018). A science teacher's complex beliefs about nature of scientific inquiry. *Nordic Studies in Science Education, 14*(1), 54-67.

Bodin, M., & Winberg, M. (2012). Role of beliefs and emotions in numerical problem solving in university physics education. *Physical Review Special Topics-Physics Education Research, 8*(1), 010108.

Borda, E. J., Burgess, D. J., Plog, C. J., DeKalb, N. C., & Luce, M. M. (2009). Concept maps as tools for assessing students' epistemologies of science. *The Electronic Journal for Research in Science & Mathematics Education,13*(2), 160-185.

Bromme, R., Kienhues, D., & Stahl, E. (2008). Knowledge and epistemological beliefs: An intimate but complicate relationship. In *Knowing, knowledge and beliefs* (pp. 423-441): Springer.

Buehl, M. M., & Alexander, P. A. (2005). Motivation and performance differences in students' domain-specific epistemological belief profiles. *American Educational Research Journal, 42*(4), 697-726.

Çam, A. (2015). Primary pre-service teachers' epistemological beliefs and their teaching and learning experiences. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(2), 381-390.

Carey, S., Evans, R., Honda, M., Jay, E., & Unger, C. (1989). 'An experiment is when you try it and see if it works': a study of grade 7 students' understanding of the construction of scientific knowledge. *International Journal of Science Education, 11*(5), 514-529.

Carter, K. (1990). Teachers' knowledge and learning to teach. *Handbook of research on teacher education.* Macmillan.

Chai, C. S., Khine, M. S., & Teo, T. (2006). Epistemological beliefs on teaching and learning: A survey among pre-service teachers in Singapore. *Educational Media International, 43*(4), 285-298.

Chai, C. S., Teo, T., & Lee, C. B. (2010). Modelling the relationship among beliefs about learning, knowledge, and teaching of pre service Teachers in Singapore. *Asia-Pacific researcher*, *19*(1), 25-42. https://doi.org/10.3860/taper.v19i1.1507

Chen, J. A., Morris, D. B., & Mansour, N. (2014). Science teachers' beliefs: Perceptions of efficacy and the nature of scientific knowledge and knowing. In *international handbook of research on teachers' beliefs* (pp. 370-386). Routledge.

Cheng, M. M., Chan, K.-W., Tang, S. Y., & Cheng, A. Y. (2009). Pre-service teacher education students' epistemological beliefs and their conceptions of teaching. *Teaching and Teacher Education*, *25*(2), 319-327.

Cho, M.-H., Lankford, D. M., & Wescott, D. J. (2011). Exploring the relationships among epistemological beliefs, nature of science, and conceptual change in the learning of evolutionary theory. *Evolution: Education and Outreach, 4*(2), 313-322.

Conley, A. M., Pintrich, P. R., Vekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary Educational Psychology*, *29*(2), 186-204.

De Vaus, D. (2007). *Research design in social research*. New Delhi: Sage.

Demirbag, M., & Bahcivan, E. (2021). Psychological modeling of pre-service science teachers' argumentativeness, achievement goals, and epistemological beliefs: A mixed design.

European Journal of Psychology of Education, 37, 257-278. https://doi.org/10.1007/s10212-021-00558-w

Dinal-Taganahan, T. (2008). *Epistemological beliefs and conceptual understanding of physics concepts: Challenge of physics teaching and research.* In proceedings of the SPVM National Physics Conference and Workshop, Central Mindanao University, Musuan Bukidnon.

Dinç, E., & Üztemur, S. (2017). Investigating student teachers' conceptions of social studies through the multi-dimensional structure of the epistemological beliefs. *Educational Sciences: Theory & Practice, 17*(6), 2093-2142.

Dogan, N., & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 45*(10), 1083-1112.

Dondofema, J., Mwenje, J., & Musemwa, L. (2020). Factors affecting Industrial Attachment Programme: Measures of academic performance and efficiency in Zimbabwe: A review. *Southern Africa Journal of Education, Science and Technology, 5*(1), 1-25.

Dorsah, P. (2020). Pre-service teachers' view of nature of science (NOS). *European journal of education studies, 7*(6), 124-146.

Epler, C. M. (2011). *The relationship between implicit theories of intelligence, epistemological beliefs, and the teaching practices of in-service teachers: A mixed methods study.* Upublished doctoeral dissertation, Virginia Polytechic institute and State University, Blacksburg, VA.

Ferguson, L. E., & Lunn Brownlee, J. (2018). An investigation of pre-service teachers' beliefs about the certainty of teaching knowledge. *Australian Journal of Teacher Education, 43*(1), 94-111. https://doi.org/10.14221/ajte.2018v43n1.6

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*. USA, Addison-Wiley.

Guo, J., Hu, X., Marsh, H. W., & Pekrun, R. (2022). Relations of epistemic beliefs with motivation, achievement, and aspirations in science: Generalizability across 72 societies. *Journal of educational psychology, 114*(4), 734-751. https://doi.org/10.1037/edu0000660

Hofer, B. K. (2001a). Personal epistemology research: Implications for learning and teaching. *Educational psychology review, 13*(4), 353-383.

Hofer, B. K. (2001b). Personal epistemology research: Implications for learning and teaching. *Educational psychology review*, *13*(4), 353-383.

Kruss, G. (2009). *Opportunities and challenges for teacher education curriculum in South Africa*. Teacher education in South Africa series. Cape Town: HSRC Press.

Kumar, R. (2011). *Research methodology: A step-by-step guide for beginners*. California: Sage Publications Limited.

Kutluca, A. Y., & Aydın, A. (2017). Changes in pre-service science teachers' understandings after being involved in explicit nature of science and socio scientific argumentation processes. *Science & Education*, *26*(6), 637-668.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of research in science teaching, 39*(6), 497-521.

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Pre-service teachers' understanding and teaching of nature of science: An intervention study. *Canadian Journal of Science, Mathematics and Technology Education, 1(2)*, 135-160.

Linn, M. C., & Hyde, J. S. (1989). Gender, mathematics, and science. *Educational researcher, 18*(8), 17-27.

Lodewyk, K. R. (2007). Relations among epistemological beliefs, academic achievement, and task performance in secondary school students. *Educational psychology*, *27*(3), 307-327.

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education, 11*(2), 38-56.

Lumpe, A., Czerniak, C., Haney, J., & Beltyukova, S. (2012). Beliefs about teaching science: The relationship between elementary teachers' participation in professional development and student achievement. *International Journal of Science Education, 34*(2), 153-166.

Lunn Brownlee, J., Curtis, E., Spooner-Lane, R., & Feucht, F. (2017). Understanding children's epistemic beliefs in elementary education. *Education 3-13, 45*(2), 191-208.

Mahler, D., Bock, D., & Bruckermann, T. (2021). Pre-service Biology teachers' scientific reasoning skills and beliefs about nature of science: How do they develop and is there a mutual relationship during the development? *Education Sciences, 11*(9), 558. https://doi.org/10.3390/educsci11090558

Mahmood, N. (2007). Elementary school science teachers' beliefs about science teaching in constructivist landscape. *Bulletin of Education & Research, 29*(2), 59-72.

Mansour, N. (2009). Science teachers' beliefs and practices: Issues, implications and research agenda. *International Journal of Environmental and Science Education, 4*(1), 25-48.

Marušić, M., & Sliško, J. (2012). Influence of three different methods of teaching physics on the gain in students' development of reasoning. *International Journal of Science Education, 34*(2), 301-326.

Mohamed, M. T., & El-Habbal, M. (2013). The relationship between epistemic beliefs and academic performance: Are better students always more mature? *Journal of Educational and Developmental Psychology, 3*(1), 158-172.

Mouton, J. (1996). *Understanding social research*: Van Schaik Publishers.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of curriculum studies, 19*(4), 317-328.

Osborne, J., Erdura, S., Simon, S., & Monk, M. (2001). Enhancing the quality of argumentation in school science. *School Science review, 82*(301), 63-69.

Özdemir, G. (2007). The effects of the nature of science beliefs on science teaching and learning. *Uludağ Üniversitesi Eğitim Fakültesi Dergisi, 20*(2), 355-372.

Ozkal, K., Tekkaya, C., Sungur, S., Cakiroglu, J., & Cakiroglu, E. (2011). Elementary students' scientific epistemological beliefs in relation to socio-economic status and gender. *Journal of science teacher education, 22*(2), 115-127.

Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS*: Routledge. https://doi.org/10.4324/9781003117452

Pallant, J. (2011). SPSS survival manual : a step by step guide to data analysis using SPSS 4th edition. Australia: Allen & Unwin.

Palmquist, B. C., & Finley, F. N. (1997). Pre-service teachers' views of the nature of science during a post baccalaureate science teaching program. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 34*(6), 595-615.

Paulsen, M. B., & Wells, C. T. (1998). Domain differences in the epistemological beliefs of college students. *Research in Higher Education, 39*(4), 365-384.

Ramnarain, U., & Padayachee, K. (2015). A comparative analysis of South African Life Sciences and Biology textbooks for inclusion of the nature of science. *South African journal of education, 35*(1), 1-8.

Sampson, V., & Benton, A. (2006). Development and validation of the beliefs about reformed science teaching and learning (BARSTL) questionnaire. In *annual conference of the Association of Science Teacher Education (ASTE), Portland, OR*.

Sampson, V., & Clark, D. (2006). The development and validation of the nature of science as argument questionnaire (NSAAQ). *In Annual Conference of the National Association for Research in Science Teaching, San Francisco, CA.*

Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science education, 89*(4), 634-656.

Schommer-Aikins, M., Duell, O. K., & Barker, S. (2003). Epistemological beliefs across domains using Biglan's classification of academic disciplines. *Research in Higher Education, 44*(3), 347-366.

Schommer-Aikins, M., Duell, O. K., & Hutter, R. (2005). Epistemological beliefs, mathematical problem-solving beliefs, and academic performance of middle school students. *The elementary school journal, 105*(3), 289-304.

Schommer, M. (1989). Students' beliefs about the nature of knowledge: what are they and how do they affect comprehension? *Center for the Study of Reading. Technical Report; no. 484*. University of Illinois.

Şen, Ö. F., & Sarı, U. (2017). Pre-service science teachers' beliefs about science teaching and perception of the nature of science. *The Electronic Journal for Research in Science & Mathematics Education, 21*(1), 1-14.

Smith, C. L., & Wenk, L. (2006). Relations among three aspects of first-year college students' epistemologies of science. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 43*(8), 747-785.

Stathopoulou, C., & Vosniadou, S. (2007a). Conceptual change in physics and physics-related epistemological beliefs: A relationship under scrutiny. In *reframing the conceptual change approach in learning and instruction*, (pp145-164). Elsevier.

Stathopoulou, C., & Vosniadou, S. (2007b). Exploring the relationship between physics-related epistemological beliefs and physics understanding. *Contemporary Educational Psychology, 32*(3), 255-281.

Thye, T., & Kwen, B. (2003). Assessing the nature of science views of Singapore preservice teachers. *In annual conference of the New Zealand/Australian Association for Research in Education in Auckland*.

Topcu, M. S. (2013). Pre-service teachers' epistemological beliefs in Physics, Chemistry, and Biology: A mixed study. *International Journal of Science and Mathematics Education, 11*(2), 433-458.

Topçu, M. S., & Yılmaz-Tüzün, Ö. (2009). Elementary students' metacognition and epistemological beliefs considering science achievement, gender and socioeconomic status. *İlköğretim Online, 8*(3), 676-693.

Vázquez–Alonso, Á., Manassero–Mas, M.-A., García–Carmona, A., & Bennàssar-Roig, A. (2014). Teachers' beliefs on science-technology-society (STS) and nature of science (NOS): Strengths, weaknesses, and teaching practice. In *topics and trends in current science education: 9th ESERA conference selected contributions* (pp. 117-135). Springer Netherlands.

Vecaldo, R. (2017). Epistemological beliefs, academic performance and teaching competence of pre-service teachers. *Asia Pacific Journal of Multidisciplinary Research, 5*(2), 114-124.

Yenice, N. (2015). An analysis of science student teachers' epistemological beliefs and metacognitive perceptions about the nature of science. *Educational Sciences: Theory & Practice, 15*(6), 1623-1636.

Yılmaz-Tüzün, Ö., & Topçu, M. S. (2013). Exploration of pre-service science teachers\'epistemological beliefs, world views, and self-efficacy considering gender and achievement. *İlköğretim Online, 12*(3), 659-673.

Yilmaz-Tuzun, O., & Topcu, M. S. (2008). Relationships among pre-service science teachers' epistemological beliefs, epistemological world views, and self-efficacy beliefs. *International Journal of Science Education, 30*(1), 65-85.

Yilmaz, H., & Sahin, S. (2011). Pre-service teachers' epistemological beliefs and conceptions of teaching. *Australian Journal of Teacher Education, 36*(1), 73-88.

Zorlu, Y. (2017). An investigation of the relationship between pre-service science teachers' epistemological beliefs about the nature of science and their self-efficacy perceptions. *Journal of Education and Practice, 8*(7), 128-137.