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Student teachers' understanding and acceptance of evolution and the nature of science

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The focus of this study was student teachers at a South African university enrolled in a Bachelor of Education (B.Ed.) programme and a Postgraduate Certificate in Education (PGCE), respectively. The purpose of this study was to explore students' understanding and acceptance of evolution and beliefs about the nature of science (NOS), and to discover if these understandings and acceptances changed with the level of their studies. In so doing, we wished to determine if there is a relationship between their understanding of evolution and the NOS, and their level of acceptance of evolution. The study is located within a quantitative framework. Questionnaires were administered to pre-service teachers, who were enrolled in the School of Education. All participants had chosen Biology as their teaching specialisation. Three instruments were included in the questionnaires. The findings revealed that students in the B.Ed. programme have a poorer understanding of evolution and NOS than the graduate group (PGCE), and that there is no significant difference in understanding between different levels within the B.Ed. group. A further significant finding was that acceptance of evolution is independent of changes in conceptual understanding of evolution and independent of changes in beliefs about the NOS.

Keywords: acceptance; beliefs; evolution; nature of science; understanding

Introduction and Background

Dobzhansky (1973) believed that the process of evolution is fundamental to an understanding of Biology, as it allows scientists to understand both past and present observations within an explanatory framework. Evolution has acquired the status of a scientific theory due to the fact that a convincing body of evidence has accumulated to support it. However, it is important to understand that all scientific knowledge is tentative, and theories may be modified as new evidence emerges. Hence there is the need to understand the principles underpinning the NOS as well.

Prior to the implementation of the National Curriculum Statement[i] in 2006, evolution was not included in the South African school curriculum. With the introduction of this curriculum, evolution, as well as the NOS, were subsequently included. However, many teachers in other African and Asian countries as well as the United States of America (USA), (Clément, 2013; Lovely & Kondrick, 2008; Mpeta, De Villiers & Fraser, 2014; Trani, 2004) have experienced problems teaching evolution. These problems include: a lack of understanding of the concept, and consequently the ability to teach the topic competently and problems with regard to the acceptance of evolution as the main organising principle in Biology, due to the fact that many people believe it contradicts their religious beliefs. This study is concerned with the former problem, as South African learners did not have the opportunity prior to 2006 to learn about evolution. Consequently, students entering teacher education programmes have been educated by teachers who themselves often did not have an adequate understanding of evolution or the NOS. The onus is therefore on higher education institutions to provide the necessary foundation for students to become competent teachers of Biology.

As a developing country, South Africa strives to compete globally in many areas, including teacher education, and competent biology teachers should demonstrate an understanding of fundamental concepts and processes, such as evolution, and the NOS. Currently, South Africa spends in excess of five percent of its gross domestic product (GDP) on education, which is a severe drain on resources. Teacher education programmes should therefore ensure that student teachers are adequately educated, and in the case of biology teachers, this would entail knowledge and understanding of evolution and the NOS. Such education is important for South African teachers to be able to compete with teachers in both the developing and developed world, with regard to their knowledge and skills pertaining to their disciplines.

The focus of this study was student teachers at a South African university enrolled in a B.Ed. programme and a PGCE, respectively. The purpose of this study was to explore students' understanding of evolution and acceptance of evolutionary theory, as well as their beliefs about the NOS, and; to discover if these understandings and acceptances changed with the level of their studies, specifically the second and fourth years of study towards a B.Ed. degree, and graduate students in the PGCE. In so doing, we wished to determine if there was a relationship between the students' understanding of evolution and their beliefs about the NOS and the level of acceptance of evolution. From an international perspective, it is important to understand how South African students, as future teachers, compare to pre-service teachers in both developing and developed countries. The critical questions that the research attempts to answer are:

- What is the difference in the level of understanding of evolution and the nature of science in students at different levels of study?
- What is the difference in the level of acceptance of evolution in students at different levels of study?
- What is the relationship between students' understanding of evolution and NOS and their acceptance of evolution?

Literature Review

Rutledge and Mitchell (2002) correctly state that evolution is the central and unifying theme of the discipline of Biology and should provide the framework for all biology courses. While this view is supported in the scientific community, the general public does not hold this view, and often rejects the teaching of evolution at secondary level (Scott, 2007). This situation has led to a proliferation of research on the teaching of evolution in schools (Aguillard, 1998; Anderson, 2007; Banet & Ayuso, 2003; Bryner, 2005; Clough, 1994; Farber, 2003; Lawson, 1999; Rutledge & Mitchell, 2002; Rutledge & Warden, 2000).

Research has found that many South African teachers have reservations about teaching evolution, due to the negative views they hold. These views may be due to the fact that they do not accept the theory of evolution (Coleman, 2006), or due to their fear of teaching a topic for which they feel under-prepared (Ngxola & Sanders, 2008). Studies have shown that for evolution to be taught effectively, teachers require a deep understanding of both the NOS and evolutionary theory (Lederman, 1992). Teachers who lack understanding of the NOS have difficulty teaching evolution for scientific understanding (Eick, 2000; Rutledge & Warden, 2000). In addition, a biology teacher's acceptance or rejection of evolutionary theory is important in terms of the central role that it plays in the biology curriculum (Rutledge & Warden, 1999). Teachers who lack understanding of the theory of evolution and the basic NOS may present the topic to learners in an isolated manner, leaving room for misinterpretations and misconceptions.

With regard to attitudes towards evolution, a number of researchers (Clough, 1994; Lawson, 1999; Sinclair & Pendarvis, 1998) are of the view that the differences between evolutionists and anti-evolutionists should be addressed in such a way that these differences are diminished. This may be achieved by adopting a constructivist approach to teaching, which requires teachers to discover what their learners know and believe (Alters & Nelson, 2002). Most South African learners are generally religious, and as a consequence, feel that they cannot accept the theory of evolution (Coleman, 2006). One way of addressing this is the adoption of sound pedagogical strategies, where evolution is presented in a scholarly manner, without attacking religion (Woods & Scharmann, 2001).

The level of understanding of the NOS and evolutionary theory and the relationship between these two aspects as well as the acceptance of evolution, have been the focus of a number of studies. Rutledge and Mitchell (2002) are of the view that specific courses in evolution and NOS should be a requirement of the subject matter preparations of biology teachers. In the South African context, it is also important that teacher education programmes include both evolution and the NOS, so as to prepare student teachers to teach biology effectively.

While addressing the needs of learners is of paramount importance, it is essential to address the factors that impact the teaching of evolution, which relate to teachers as well (Rutledge & Mitchell, 2002). While a considerable body of knowledge exists with regard to teacher opinions and attitudes concerning the evolution-creation controversy (Banet & Ayuso, 2003; Bryner, 2005; Van Koevering & Stiehl, 1989), very little research has been conducted on teachers' understanding of evolutionary theory (Rutledge & Warden, 2000). Many high school biology teachers in the South African context have no formal training in the principles and mechanism of evolution as a biological process. Keke (2014), in a study of 147 secondary biology teachers, found that teachers expressed the greatest need for professional development in topics relating to evolution from all the topics in the Grade 10-12 life sciences curriculum.

Research suggests that conceptual understanding in Science is facilitated when the Science learnt is deemed interesting to the learner as well as relevant to his or her everyday life (Taylor, 2001). Earlier work by Hewson (1981), Posner, Strike, Hewson and Gertzog (1982) has attempted to explain how conceptual change occurs by defining a theory of conceptual exchange (or accommodation). This theory foregrounds a notion of 'competition' between the conceptions that students hold and any new concepts with which they are confronted. For students to change their existing conceptions, these researchers believe accommodation needs to occur. For accommodation to occur, Posner et al. (1982) are of the view that four conditions need to be met. The first step is that a student develops dissatisfaction with the existing conceptions he/she may hold. Once this occurs, the student may exchange this conception with a new conception on condition that the competing conception is intelligible, plausible and fruitful. More recent work on the nature of conceptual understanding has been reported by Clark (2006), DiSessa, Gillespie and Esterly (2004) and others, who propose different models of how conceptual change occurs. One such model views understanding in terms of collections of multiple quasi-independent elements (Özdemir & Clark, 2007).

The question arises as to whether these existing models of conceptual change apply in situations where the topic being studied presents concepts that are counter-intuitive. Evolution is such a topic. Students find it very difficult to align their existing views with the new views presented to them when engaging with evolutionary biology. This creates a resistance to the new concepts, and understandably hampers understanding. Under these circumstances it may be more helpful to examine student conceptual understanding within a framework of resistance. An example of such a framework is a model proposed by Jegede (1995), known as collateral learning. This model defines collateral learning as an accommodative mechanism for the conceptual resolution of potentially conflicting tenets within a person's cognitive structures. Collateral learning was proposed as an explanatory model to understand the conflict arising when learners from non-western cultures are faced with a western world-view. It represents the process whereby a learner in a non-western classroom simultaneously constructs, with minimal interference and interaction, western meanings of a simple concept (Jegede, 1995). This model facilitates the holding of a scientific as well as a traditional view of the world. This is in contrast with the conceptual change framework, where learners would have to replace their prior concepts with currently accepted western science concepts. Students often see very little relevance in learning about evolution (Coleman, 2006) as they are not able to relate it to their everyday lives. Jegede's (1995) model of collateral learning may therefore apply to the learning of evolution, as many evolutionary concepts are counter-intuitive. Previous research has found that even teachers often find it difficult to understand concepts pertaining to evolution (Kirsten, 2014).

The difficulty teachers face with regard to the teaching of evolution appears to be compounded by their poor understanding of the NOS. Abd-El-Khalick and Lederman (2000) have demonstrated that both teacher and learner beliefs about the NOS are inconsistent. The way a teacher understands the NOS may influence the way he/she teaches science, and in particular, evolution. This in turn, has an influence on the way learners understand Science, and this may be particularly problematic with a topic such as evolution, where so many misconceptions abound. Similar findings have been obtained by Brickhouse (1990), Shulman (1986) and Singh (1998). Hammrich (1997) is also of the view that the conceptions teachers hold of the NOS shape their understanding of science, as well as of how science should be taught. These conceptions are firmly entrenched as their epistemologies with regard to science were influenced by their socialisation as teachers, as well as the way they were taught as learners.

Lederman is of the view that the NOS may be regarded as the cornerstone in the teaching of Science as a subject. It is for this reason that science curricula in many countries agree on the "development of an adequate understanding of the NOS" (Lederman, 1992:331). An important observation made by Lederman (1992), was that teaching experience does not contribute to a teacher's understandings of the NOS. A teacher's view of the NOS does, therefore, not change through experience, but because of a change in his/her view of what constitutes science. It is therefore important that education courses address the issue of the NOS, as research shows the knowledge that pre-service teachers have of the NOS to be inadequate (Irez, 2006). Research by Abd-El-Khalick (2001) and Abd-El-Khalick and Akerson (2004) has further shown that implicit teaching of NOS through enquiry-based courses is less successful than explicit teaching of how to teach the NOS as covered in methods courses in science education programmes. It is thus incumbent on the developers of science education courses to include the teaching of the NOS in their curricula. This study will contribute to the understanding of teachers' views of the NOS, obtained from the courses they attended at university.

While a lack of understanding may influence students' acceptance of evolution, religious views or the views of the community from where the students come may have a similar impact (Evans, 2001). On the other hand, a better understanding of evolutionary biology has not/does not necessarily lead to a general social acceptance of evolution as a scientific fact (Bishop & Anderson, 1990).

Methods

This study replicates a study conducted by Cavallo and McCall (2008), who reported that ninth-grade biology students improved their knowledge of evolution after a unit of instruction on evolution, but did not change their beliefs about the NOS or acceptance of evolution. The research is located within a quantitative framework. Questionnaires were administered to 200 pre-service teachers (hereafter referred to as students), who were enrolled in the School of Education at a tertiary institution in South Africa in 2012. Incomplete questionnaires were discarded. As a result, the responses of 164 students were analysed.

Sample

Participants were either enrolled in a B.Ed. degree (n = 128), or in a PGCE programme (n = 36). Both groups were Biology/Life Sciences majors. The B.Ed. degree is a professionally focused degree, in which students construct their subject matter knowledge as appropriate for teachers. They do not attend mainstream science courses, which are intended for students studying towards a Bachelor of Sciences degree. Their biology programme includes a substantial theme on evolution and all modules are approached from the premise that evolution is the underlying principle that informs all biology teaching. Postgraduate Certificate in Education (PGCE) students have Bachelor of Science (B.Sc.) degrees, and only focus on education in the PGCE programme. The minimum requirements for registration as a biology teacher are at least two years of study in disciplines related to Biology. The extent to which students are exposed to the NOS and evolution depends on the structure of the degree, which may differ between various institutions. The students who constituted the sample of the study, were representative of the student population of the university at which the research was conducted, that is, approximately 75% of the students do not have English as their home language. Data concerning gender and year of matriculation was collected. Year of matriculation proved particularly important, since 2008 marked the first cohort of school-leavers who had studied evolution during their schooling.

The codes for the modules students participating in the study were registered for, were Biological Sciences for Educators BIO210, BIO 410 and BIO610. The BIO210 group of students were in their second year of study towards a B.Ed., but were in the first year of study for the course BIO210. Females constituted 56% of the class, and males 44% of the class. The majority of students (93%) had matriculated between 2008 and 2010, with only 7% having matriculated in 2007 or earlier.

The BIO410 group of students were in their fourth year of study towards a B.Ed. degree, and the third year of studying BIO410. Females constituted 59% of the class, and males 41% of the class. A minority of students (39%) had matriculated in 2008, with the majority (61%) having matriculated in 2007, or earlier.

The BIO610 group were studying towards a PGCE, and all were registered for the Biology Teaching Specialisation module. Females constituted 58%, and males 42% of the group. All students had matriculated in 2007 or earlier.

The three groups were therefore similar in gender representation, but differed in exposure to evolution in their schooling. Most of the BIO210 group had been taught evolution during schooling, while only 39% of the BIO410 group and none of the BIO610 group had experience studying evolution as part of their schooling. All three groups had a similar proportion of English home-language speakers. Statistical comparisons among the three groups were therefore valid.

Data Collection and Procedure

The questionnaire consisted of five sections:

Section A of the questionnaire collected basic demographic data. In addition, students were asked whether evolutionary ideas were in conflict with their religious beliefs. Section B, which covered students' worldviews, was not utilised for the present study. We administered three instruments as follows.

Section C

To assess students' acceptance of evolutionary theory, the Measure of the Acceptance of the Theory of Evolution (MATE) (Rutledge & Warden, 1999) was administered. This section of the questionnaire consisted of 20 statements and was scored using a Likert scale. The response indicating strongest degree of acceptance of the theory of evolution received a score of 5, and the response indicating least degree of acceptance of the theory of evolution received a score of 1. Thus, the possible range of total scores was 20–100.

Section D

To assess students' beliefs about the NOS, a questionnaire consisting of 17 items was used (Rutledge & Warden, 2000). The items were scored using a Likert scale. The response most congruent with science received a score of 5, and the response least congruent with science received a score of 1. Thus, the possible range of total scores was 17–85.

Section E

To assess students' understanding of evolutionary theory, 21 multiple choice items were administered to students (Rutledge & Warden, 2000). These items addressed various aspects of evolutionary theory. For each item, a choice of five possible answers was presented. The number of correct responses was tallied, and a cumulative score obtained. The possible range of scores was 0–21. This variable will hereafter be referred to as 'MCQ' (multiple choice questions).

Data Analysis

Data was scanned, and cleaned, before statistical analysis was conducted. Candidates' responses were deleted if they did not comply with the following criteria:

1. Completed all three surveys;
2. Omitted less than five questions in the Evolution Understanding test. This criterion was introduced after it became apparent that a number of students failed to answer questions after they reached a certain point. It was not clear whether this was due to test fatigue, lack of knowledge or refusal to answer the questions. The number of students eliminated by each criterion is shown in Table 1.

Table 1 Number and percentage of students eliminated by each criterion

Group	Did not answer MATE	Did not answer NOS	Did not answer MCQ	Omitted ≥ 5 MCQ questions
210 (n = 97)	13 (13.4%)	1 (1.0%)	17 (17.5%)	1 (1.0%)
410 (n = 31)	0	0	0	2 (6.5%)
610 (n = 36)	0	1 (2.9%)	0	16 (45.7%)

The excluded students are important, in that they indicate that answering the NOS survey was more acceptable to all three groups than answering the MATE or the Understanding Evolution questions for the 210 group. It is also significant that 45.7% of the 610 group omitted more than four questions on the multiple-choice test, and were therefore excluded from the final sample. Some students satisfied two or more criteria for exclusion. This process eliminated 22 students from the 210 group, two from the 410 group, and 16 from the 610 group. The percentage of participants who therefore completed the questionnaire was 75.6 percent.

The instruments used had been developed and validated by previous researchers (Cavallo & McCall, 2008; Rutledge & Warden, 2000). Minor adaptations related to simplifying the language in the questionnaire were made to suit the South African context. However, the reading level required to answer many of the questions may have resulted in many incomplete questionnaires, since the majority of students participating in the study were not English first-language speakers. There was evidence of resistance to participation in the collection of data, and one group of students (the 310 class) was abandoned entirely, due to the sheer number of incomplete questionnaires.

Although the respondents were mostly students of one of the researchers, questionnaires were completed voluntarily. Furthermore, respondents were assured of their anonymity. The ethics committee of the university where the research was conducted gave permission for the research to be conducted.

Results

Table 2 provides the results, which enabled us to answer the first two research questions. The mean scores obtained on each questionnaire were compared among the three groups of students, 210, 410 and 610. Summary statistics are shown in Table 2. A one-way analysis of variance was conducted to compare the mean scores across student groups in each part of the survey.

Table 2 Summary statistics and results of ANOVA comparison of group means for each variable

Variable	Class	n	Mean score	SD	F (2 df)	Sig.	Multiple comparisons
Evolution understanding (max = 21)	210	75	7.6	2.2			610 > (210, 410)
	410	29	7.9	2.2	5.6	0.005	
	610	20	9.7	3.6			
NOS Beliefs (max = 85)	210	75	51.0	5.2			
	410	29	53.6	3.9	14.6	< 0.001	610 > (210, 410)
	610	20	57.7	5.4			
Acceptance of evolution (max = 100)	210	75	72.0	10.8			
	410	29	73.2	10.2	0.2	0.9	No significant differences
	610	20	73.1	15.2			

Note: ANOVA: analysis of variance; SD: Standard deviation; Sig: significance; df: degrees of freedom.

The mean scores for the understanding of evolution were low across the three groups, given that the maximum possible score is 21. However, the graduate group (610) obtained significantly higher scores than did the two B.Ed. groups (210 and 410). The mean score obtained by fourth-year students (410) was non-significantly higher than the mean score obtained by second year students (210). Students in the B.Ed. programme therefore have a poorer understanding of evolution than the graduate group (it ought to be mentioned that this research was conducted before the section on evolution was covered in the 410 module; however at this stage, students had studied four biology modules).

Beliefs about the NOS revealed that the graduate group (610) also obtained significantly higher mean scores than did the two B.Ed. groups (210 and 410). The mean score obtained by fourth year students (410) was non-significantly higher than that obtained by second year students (210).

Mean scores for the Acceptance of Evolution were high in all three groups (over 70% in all groups), and did not differ significantly among the three groups. This suggests that factors other than level of knowledge about evolution and the NOS are implicated in students' acceptance of evolution. A more nuanced analysis is possible if the proportion of students choosing each option (1–5) is analysed. This is shown in Figure 1 for acceptance of evolution.

The frequency of selection of each level from 1 (Strongly Disagree) to 5 (Strongly Agree) was plotted as percentages of the total number of selections made by students in each module (Figure 1). Over 60% of answers given in all three classes accepted the theory of evolution (scored as 4 or 5), while less than 20% of the answers indicated rejection of the theory of evolution (scored as 1 or 2). All three groups had similar profiles, shown in Figure 1. The chi-squared statistic comparing the proportion of choices for levels 1 to 5 in the three groups was significant (chi-squared = 16.72, $p < 0.05$). The z-scores indicated that there was no difference among the three groups in the selection for levels 1, 2 and 3. Level 4 (Agree) was significantly more frequently selected by the 410 group than the 610 group, with the 210 group straddling both groups. However, the reverse was found for level 5 (Strongly Agree), with the 610 group being significantly more likely to choose this option than the 210 group, and the 410 group straddling the 210 and 610 groups.

Figure 1 and the chi-squared analysis reveal an increase in the acceptance of evolution between the 210 and 410 modules, as indicated by fewer 410 students refusing to answer this questionnaire, and more 410 students agreeing or strongly agreeing with statements about evolution. The 610 students were more certain about their acceptance of evolution than any other group, but they were equally as likely to disagree as B.Ed. students.

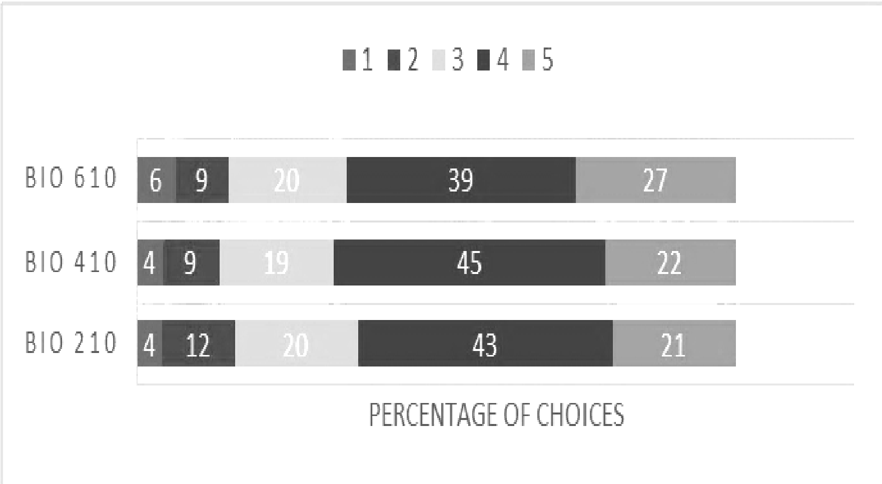

Figure 1 Frequency of selection of each level from 1 (Strongly Disagree) to 5 (Strongly Agree) with statements about acceptance of evolution

Figure 2 shows the results of the NOS survey, which indicates a greater difference between the PGCE and B.Ed. students than was seen in the results of the MATE survey. This observation is supported by the results of a chi-squared test comparing the proportion of choices for levels 1 to 5 (1 = non-scientific, 5 = scientific) in the three student groups being highly significant (chi-squared = 33.81, $p < 0.001$). The 210 group was significantly more likely to have strongly non-scientific beliefs than either the 410 or 610 groups, but groups did not differ significantly on moderately non-scientific beliefs or indecision. The 610 group was significantly more likely to hold scientific beliefs than the 210 group, with the 410 group straddling both groups. The 610 group was significantly more likely to hold strongly scientific beliefs (level 5) than either of the other two groups. The marked difference between the B.Ed. and the PGCE groups is made apparent when the total "agreement" is calculated: 54% of the responses for the 610 group indicated acceptable beliefs with regard to the NOS, while 44% of 410 students and 42% of 210 students had the same responses.

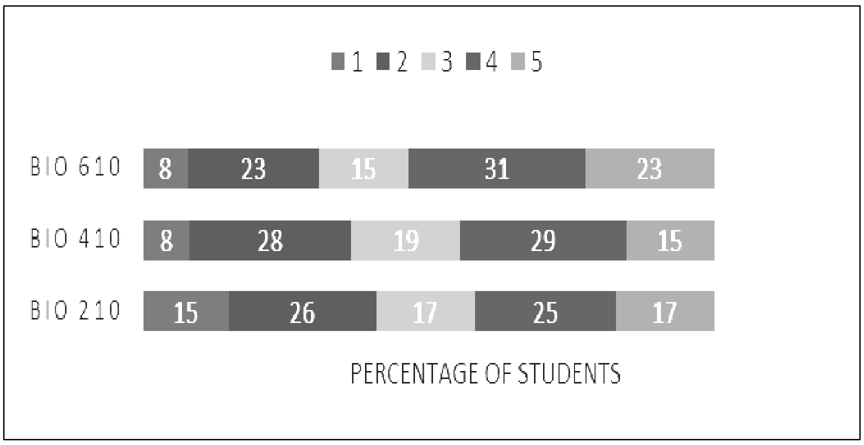

Figure 2 Frequency of selection of each level from 1 (Strongly Disagree) to 5 (Strongly Agree) with statements about the nature of science

The results shown here support the findings of the ANOVA that the 610 group displayed better understanding of the NOS than either the 210 or 410 group. The results of the chi-squared test show that the 410 group had a somewhat better understanding of the NOS than the 210 group, but it is not a convincing improvement. The 210 group were equally split between scientific and non-scientific beliefs about the nature of science.

A linear regression analysis was performed to investigate the relationship among the three variables for all three groups combined. These results enabled us to answer our third critical question. Predictions are that knowledge of evolution would correlate positively with acceptance of evolution and understanding of the NOS. Pearson Correlation coefficients are shown in Table 3.

All variables are positively correlated with one another, but only one correlation is highly significant, namely that between understanding of evolution and beliefs about the NOS ($p < 0.001$). Acceptance of evolution is not significantly positively correlated with either evolution understanding or acceptable beliefs about the NOS. Table 3 shows that both evolution understanding and acceptable beliefs about the NOS were significantly higher in the graduate group than in the undergraduate groups, but that acceptance of evolution did not differ by group of students. The linear regression reinforces that acceptance of evolution is independent of evolution understanding and independent of beliefs about the NOS.

Table 3 Pearson correlations between Evolution understanding, Acceptance of Evolution and beliefs about Science

	Evolution Understanding	Acceptance of Evolution
Acceptance of Evolution	0.123	
NOS Beliefs	0.332**	0.056

Discussion and Conclusion

Compared with the data collected by Cavallo and McCall (2008) using the same three instruments used here, South African pre-service teachers have more acceptable beliefs about the NOS, as well as a higher level of acceptance of evolution. This is in accordance with the research conducted by Mpeta et al. (2014), who found that there was a moderate acceptance of evolution by learners in the Limpopo province of South Africa; but contrary to the findings of Peker, Comert and Kence (2010), who report low levels of acceptance of students in Turkey. Schröder (2013) is of the view that low levels of acceptance of evolution may be interpreted as resistance to change, regardless of increase in knowledge. This study supports this view, as high levels of acceptance of evolution were evident, irrespective of the level of students' understanding. Sinatra, Southerland, McConaughy and Demastes (2003) report similar findings. In the South African context, the reason for this may be that, in spite of low levels of understanding, attitudes to evolution may be changing. While evolution was formerly treated as a controversial issue, and met with resistance when introduced into the South African school curriculum (Sanders, 2008), it would appear that it is no longer as controversial. Students enter university courses having been exposed to evolution concepts and are taught courses in Biology by staff who accept evolution as a scientific fact. Students' acceptance of evolution is therefore possibly strengthened by the measure of exposure they have had to teachers and lecturers who teach evolution as an integral part of the discipline, irrespective of the level of knowledge of evolution concepts. This is a positive development, as acceptance of such a fundamental aspect of the discipline is very important for student teachers who wish to become competent teachers of Biology.

With regard to the understanding of evolution only the graduate students in our study match the level of understanding of evolution achieved in the post-test by the ninth-grade students sampled by Cavallo and McCall (2008). This lack of knowledge of concepts relevant to evolution is clearly a cause for concern, as all teachers of Biology/Life Science should demonstrate adequate knowledge of evolution and the NOS. Many students were eliminated from the data analysis because they were unable or unwilling to answer many of the questions in the questionnaire. It is also a concern that the B.Ed. students had a relatively poor understanding of the NOS, which was considerably stronger in the PGCE students. The reason for students' poor understanding of evolution may be twofold. Firstly, students' lack of understanding of NOS may contribute to their lack of understanding of evolution. This was confirmed by the research conducted by Eick (2000), and Rutledge and Warden (2000), who respectively found that those teachers who lack understanding of the NOS, have difficulty teaching evolution for scientific understanding. However, the students in this study have acceptable beliefs of NOS, although their knowledge of concepts related to NOS may be lacking. Secondly, students may resist conceptual change, because the concepts related to evolution are counter-intuitive. Deeper engagement with concepts related to evolution and NOS are required in order to facilitate conceptual change. This explains why the PGCE students have a better understanding of evolution and NOS than the B.Ed. students, as they probably engaged more deeply with these concepts in a pure science degree.

This research points to a possible lack of emphasis on evolution and NOS in biology courses. More time should be spent on these concepts, not only as important concepts, but also as guiding principles in the design of these courses. If evolution and the NOS are taught as an integral part of Biology in all modules, including method modules, students may be able to engage at a deeper level, and develop a better understanding of these important concepts. This is especially applicable to students in B.Ed. programmes. While the focus may be education, it is important that students gain in-depth knowledge and understanding of the concepts pertaining to their specialisations. As a developing country, South Africa cannot afford to produce teachers who lack fundamental knowledge of the disciplines they will be teaching.

This study provides base-line data on the level of understanding of the NOS and the level of understanding and acceptance of evolution in life sciences student teachers at a single higher education institution in South Africa. The findings of this study may provide valuable information for tertiary institutions more generally, in terms of the design of their biology programmes for student teachers; and in addition allow comparisons to be made between South African pre-service teachers, with those in other countries. Furthermore, a country such as South Africa, which experiences a number of extreme economic constraints, ought to consider the allocation of funding for professional development courses for teachers very carefully. The findings of this study may therefore contribute to the process of identifying where in the country the need for professional development of life sciences teachers is greatest.

Notes

i. The first post-apartheid curriculum implemented in South Africa.

References

Abd-El-Khalick F 2001. Embedding nature of science instruction in pre-service elementary science courses: Abandoning scientism, but… . *Journal of Science Teacher Education,* 12(3):215-233. doi: 10.1023/A:1016720417219

Abd-El-Khalick F & Akerson VL 2004. Learning as conceptual change: Factors mediating the development of preservice elementary teachers' views of the nature of science. *Science Teacher Education,* 88(5):785-810. doi: 10.1002/sce.10143

Abd-El-Khalick F & Lederman NG 2000. The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching (JRST),* 37(10):1057-1095. doi: 10.1002/1098-2736(200012)37:10<1057::AID-TEA3>3.0.CO;2-C

Aguillard DW 1998. An analysis of factors influencing the teaching of biological evolution in Louisiana public secondary schools. Doctoral thesis. Baton Rouge, LA: Louisiana State University and Agricultural & Mechanical College.

Alters BJ & Nelson CE 2002. Perspective: Teaching evolution in higher education. *International Journal of Organic Evolution,* 56(10):1891–1901.

Anderson RD 2007. Teaching the theory of evolution in social, intellectual, and pedagogical context. *Science Education,* 91(4):664–677. doi: 10.1002/sce.20204

Banet E & Ayuso GE 2003. Teaching of biological inheritance and evolution of living beings in secondary school. *International Journal of Science Education,* 25(3):373-407. doi: 10.1080/09500690210145716

Bishop BA & Anderson CW 1990. Student conceptions of natural selection and its role in evolution. *Journal of Research in Science Teaching,* 27(5):415-427. doi: 10.1002/tea.3660270503

Brickhouse NW 1990. Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education,* 41(3):53-62. doi: 10.1177/002248719004100307

Bryner J 2005. Teaching evolution. *Instructor,* 115(2):37–39.

Cavallo AML & McCall D 2008. Seeing may not mean believing: Examining students' understandings and beliefs in evolution. *The American Biology Teacher,* 70(9):522-530. http://dx.doi.org/10.1662/0002-7685-70.9.522

Clark DB 2006. Longitudinal conceptual change in students' understanding of thermal equilibrium: An examination of the process of conceptual restructuring. *Cognition and Instruction,* 24(4):467-563.

Clément P 2013. Muslim teachers' conceptions of evolution in several countries. *Public Understanding of Science.* doi: 10.1177/0963662513494549

Clough MP 1994. Diminish students' resistance to biological evolution. *American Biology Teacher,* 56(7):409–415.

Coleman J 2006. *The FET curriculum and the teaching of evolution – what are the challenges facing teachers?* Paper presented at the 3rd Biennial Conference of the South African Association for Science and Technology Educators, 3-6 July, University of KwaZulu-Natal, Durban, South Africa.

DiSessa AA, Gillespie NM & Esterly JB 2004. Coherence versus fragmentation in the development of the concept of force. *Cognitive Science,* 28(6):843-900. doi: 10.1207/s15516709cog2806_1

Dobzhansky T 1973. Nothing in biology makes sense except in the light of evolution. *The American Biology Teacher,* 35(3):125-129.

Eick CJ 2000. Inquiry, nature of science and evolution: The need for a more complex pedagogical content knowledge in science teaching. *Electronic Journal of Science Education,* 4(3):1-14. Available at http://ejse.southwestern.edu/article/view/7633/5400. Accessed 17 March 2015.

Evans EM 2001. Cognitive and contextual factors in the emergence of diverse belief systems: Creation versus evolution. *Cognitive Psychology,* 42(3):217-266. http://dx.doi.org/10.1006/cogp.2001.0749

Farber P 2003. Teaching evolution & the nature of science. *The American Biology Teacher,* 65(5):347-354.

Hammrich PL 1997. Confronting teacher candidates' conceptions of the nature of science. *Journal of*

Science Teacher Education, 8(2):141-151. doi: 10.1023/A:1009470424752
Hewson PW 1981. A conceptual change approach to learning science. *European Journal of Science Education,* 3(4):383-396. doi: 10.1080/0140528810304004
Irez S 2006. Are we prepared?: An assessment of pre-service science teacher educators' beliefs about nature of science. *Science Education,* 90(6):1113-1143. doi: 10.1002/sce.20156
Jegede OJ 1995. Collateral learning and the eco-cultural paradigm in science and mathematics education in Africa. *Studies in Science Education,* 25(1):97-137. doi: 10.1080/03057269508560051
Keke B 2014. Understanding life sciences teachers' engagement with ongoing learning through continuous professional development programmes. Doctoral thesis. Pietermaritzburg: University of KwaZulu-Natal.
Kirsten F 2014. Life sciences teachers' understanding of the nature of science within the context of teaching evolution. Master's dissertation. Durban: University of KwaZulu-Natal.
Lawson AE 1999. A scientific approach to teaching about evolution & special creation. *The American Biology Teacher,* 61(4):266-274.
Lederman NG 1992. Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching (JRST),* 29(4):331-359. doi: 10.1002/tea.3660290404
Lovely EC & Kondrick LC 2008. Teaching evolution: challenging religious preconceptions. *Integrative & Comparative Biology,* 48(2):164–174. doi: 10.1093/icb/icn026
Mpeta M, De Villiers JJR & Fraser WJ 2014. Secondary School Learners' Response to the Teaching of Evolution in Limpopo Province, South Africa. *Journal of Biological Education.* doi: 10.1080/00219266.2014.914555
Ngxola N & Sanders M 2008. *Teaching evolution in the new curriculum: Life Sciences teachers' concerns.* Proceedings of the Sixteenth Annual Conference of the South African Association for Research in Mathematics, Science and Technology Education. University of Lesotho, Maseru, Lesotho.
Özdemir G & Clark DB 2007. An overview of conceptual change theories. *Eurasia Journal of Mathematics, Science & Technology Education,* 3(4):351-361. Available at http://www.ejmste.org/v3n4/EJMSTE_v3n4_Ozdemir_Clark.pdf. Accessed 20 March 2015.
Peker D, Comert GG & Kence A 2010. Three Decades of Anti-evolution Campaign and its Results: Turkish Undergraduates' Acceptance and Understanding of the Biological Evolution Theory. *Science & Education,* 19(6-8):739-755. doi: 10.1007/s11191-009-9199-1
Posner GJ, Strike KA, Hewson PW & Gertzog WA 1982. Accommodation of a science conception: Toward a theory of conceptual change. *Science Education,* 66(2):211-227. doi: 10.1002/sce.3730660207
Rutledge ML & Mitchell MA 2002. High school Biology teachers' knowledge structure, acceptance & teaching of evolution. *The American Biology Teacher,* 64(1):21-28.
Rutledge ML & Warden MA 1999. The development and validation of the measure of acceptance of the theory of evolution instrument. *School Science and Mathematics,* 99(1):13-18. doi: 10.1111/j.1949-8594.1999.tb17441.x
Rutledge ML & Warden MA 2000. Evolutionary theory, the nature of science & high school Biology teachers: Critical relationships. *The American Biology Teacher,* 62(1):23-31.
Sanders M 2008. *Teaching about "Evolution". More than just knowing the content!* Paper presented at the 4th biennial conference of the South African Association of Science and Technology Education, 1-4 July, University of the Witwatersrand Johannesburg, South Africa.
Schröder DD 2013. An investigation into the attitudes of teachers and learners towards evolution, the conceptual changes that occur when learners are taught evolution, and the factors that influence this conceptual change. Master's dissertation. Pietermaritzburg: University of KwaZulu-Natal.
Scott EC 2007. What's wrong with the "Teach the Controversy" slogan? *McGill Journal of Education,* 42(2):307-315.
Shulman LS 1986. Those who understand: Knowledge growth in teaching. *Educational Researcher,* 15(2):4-14. doi: 10.3102/0013189X015002004
Sinatra GM, Southerland SA, McConaughy F & Demastes JW 2003. Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching (JRST),* 40(5):510-528. doi: 10.1002/tea.10087
Sinclair A & Pendarvis MP 1998. Evolution versus conservative religious beliefs: Can biology instructors assist students with their dilemma? *Journal of College Science Teaching,* 27(3):167-170.
Singh SK 1998. Exploring teachers' beliefs about the nature of science and their relationship to classroom practices: a case study with special reference to physical science teachers in the Empangeni/Richards Bay area. MEd thesis. Durban: University of KwaZulu-Natal.
Taylor JA 2001. Using a practical context to encourage conceptual change: An instructional sequence in bicycle science. *School Science and Mathematics,* 101(3):117–124. doi: 10.1111/j.1949-8594.2001.tb18014.x
Trani R 2004. I won't teach evolution; *It's against my religion.* And now for the rest of the story… .*The American Biology Teacher,* 66(6):419-427.
Van Koevering TE & Stiehl RB 1989. Evolution, creation & Wisconsin Biology teachers. *The American Biology Teacher,* 51(4):200-202.
Woods CS & Scharmann LC 2001. High school students' perceptions of evolutionary theory. *Electronic Journal of Science Education,* 6(2). Available at http://wolfweb.unr.edu/homepage/crowther/ejse/woodsetal.html. Accessed 20 June 2012.