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Preservice Teachers' Level of Knowledge on Elements and Rationale for Nature of Science: Towards Advancing Quality Instruction

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Abstract: This study investigates preservice teachers' knowledge of elements and rationale for Nature of Science (NOS). Skill gap is established in the literature on pedagogical practices of preservice as well as novice teachers of science, reflecting deficiency in their professional training and eventual classroom practice. Examining preservice teachers' knowledge in these aspects (elements & rationale) of NOS through a quasi-experiment of one-group pretest and post-test design was done. Instructional intervention over two years along with assignments and presentation with researchers as moderators on the science pedagogy module (History of Science and Philosophy of Science) serves as stimuli over the period. Three research questions and two hypotheses were raised to guide this study. One hundred and thirty-six (112 Life Science and 24 Physical Science) preservice teachers were the participants. Element of NOS (ENOS) and Rationale for NOS (RNOS) were the instruments. Reliability of the instruments yielded Cronbach alpha values of .83, .91 and .86 across dimensions of clarity, coherence and relevance by fifteen experienced science educators. Data was analysed using t-test and ANCOVA. The study found the intervention to effectively improve the knowledge of elements and rationale for NOS. Better prepared teachers (More Knowledge Order [MKO] have the potential to improved Zone of Proximal Development [ZPD] in learners) by implication have the competence to guide learners for qualitative and effective learning. The instruments in this study is recommended for foundational training of preservice teachers on NOS for enhanced instruction.

Keywords: *elements, NOS, preservice reachers, rationale, instruction.*

Introduction

This opening paragraph provides basic knowledge of Nature of Science (NOS) to novice audience to assist their understanding of succeeding paragraphs. Culture may be regarded as a way of life of a people. Such people are known for their traits, practices and ways which distinguishes them from others. Culture and tradition are amalgamated into history. Like other fields of knowledge or discipline, science is with its culture, tradition and history. In this instance, scientist have observation and experimentation as means of drawing inferences. The inferences drawn culminate into new knowledge which assist in better understanding of nature. Postulation, hypotheses (assumptions), theories and laws are traditional to science, and it processes. New knowledge often evolves from an assumption which is usually the starting point. However, the technology available for discovery at a particular time determines the extent of knowledge evolution. The umbrella name for culture, tradition and history is characterised as nature. The culture, tradition and history of science may literarily mean Nature of Science (NOS) without denouncing its philosophical and epistemological limits. Impacting the knowledge of science is science education, and science educator/teachers own this prerogative. Integrating NOS into classroom practices of science teachers for instruction has gained prominence. Storytelling, rote memorisation and field trip were ways of impacting the knowledge of science before now. Inquiry, argumentation among others have proven to better support learners' needs in recent time.

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Positions in the literature have establish the need to improve the teaching of science through NOS integration (Bartos and Lederman, 2014; Clough, 2018; Mesci, 2020; Nouri and McComas, 2019; Yacoubian, 2021). Previous scholarly arguments have evolved the contexts [contextualised and decontextualised] (McComas, 2020; Mulvey and Bell, 2017; Wahbeh and Abd-El-Khalick, 2014; Wheeler et al., 2019), approaches [implicit and explicit] (McComas and Clough, 2020; Nouri and McComas , 2019; Nouri et al., 2021; Sweeney and McComas, 2022; Yacoubian, 2021) and explicit reflective integration (Hanuscin, 2013; Lederman et al., 2019; Vygotsky and Cole, 1978, p. 86; Wahbeh and Abd-El-Khalick, 2014). There is no doubt on the need to improve the way science is taught owing to growing demand and the need for expertise in Science Technology Robotics Engineering Arts (aesthetics) and Mathematics (STREAM) and the responsibility therewith (Abd-El-Khalick and Lederman 2000; Clough, 2018). Furthermore, attempts have been made by stakeholders to up-skill practising teachers to integrate NOS in their instruction. An effort which is usually driven by on-the-job training which deviates from the traditional way preservice content are structured. Those effort mostly arose from capacity building workshops, training and occasional self-development (Badmus and Jita, 2022). Substantively, what is required of science teacher educators and trainers for the training of preservice teachers on NOS instruction for improved practice has a place in the literature. In addition, science teacher educator in research and practice have identified competencies required by teachers for NOS integration (Nouri et al., 2021).

Developing preservice science teachers' NOS integration capacity to better facilitate students' learning and conceptualisation remain important in science education. For this goal to be achieved, teacher training and development should be prioritised. Recent studies have provided guidance on NOS integration (Alameh et al., 2023, Alameh and Abd-El-Khalick, 2018; Lederman and Lederman, 2019), NOS competencies (Nouri et al., 2021), structural elements of scientific explanations as well as models for teaching NOS and questionings (Allchin, 2017; Khishfe, 2022) to guide science teachers practices. Positions deducible from literature suggest that sizeable attention has been given to teacher development on the job and not teacher training before certification with respect to NOS integration. The study of Vygotsky and Cole, 1978, p. 86) identified convergent, divergent and evaluative questioning in student-centred classroom while Alameh et al., (2023) researched the nature of scientific explanations with emphasis on goodness and quality of explanations by college students, teachers and scientist to emphasize the importance of qualitative scientific explanations. Answers have also been availed in the literature regarding the construction of scientific explanations to suit students' conceptualisation of science (National Research Council [NRC], 2012). A shift from teacher development to Students' knowledge of NOS through socio-scientific issues has also added to the debate on NOS and its integration (Kahn and Zeidler, 2019; Khishfe, 2017, 2019, 2022; Lederman et al., 2014). Arising from the forgoing, adequate attention is required in preservice science teacher training especially when guidance on competencies, quality of explanations and more are well grounded within scholarly depth.

Teacher training forms the basis upon which professional and further development are built, especially for science teachers and science teacher educators. As such, preservice teacher training on NOS integration, competencies, models, templates and frameworks for pedagogical and didactic synchronisation with the curriculum is yet to gain prominence. Admittedly, possible variations may exist with respect to implementation and the universality of the curriculum components. However, presently lacking in the literature are foundational templates to guide the training of preservice teachers on the rationale and elements for NOS and its modes of assessment. Today's teachers are a product of prior academic and professional development. Evidently, inadequacies have been established in the literature regarding classroom practices of science teachers with respect to the quality of explanations students are availed (Alameh and Abd-El-Khalick, 2018; Mesci and Schwartz, 2017n with more capable peers'; Tang, 2016). To substantiate the afore-stated, Erduran (2006) documented the difficulties both students and teachers encounter when constructing scientific explanations. Furthermore, scholars have posited the existence of competence gap in teachers as reflected in explanations provided to students in science on scientific processes. It becomes imperative to improve science teacher training for preservice teachers on NOS, especially its integration to improve their pedagogical and didactic skills.

Theoretical Framework

Vygotsky defined zone of proximal development as 'the distance between the actual development level (of the learner) as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers' (Vygotsky and Cole, 1978, p. 86)

Lev Vygotsky in 1978 proposed the theory of learning and development with More Knowledge Order (MKO) and Zone of Proximal Development (ZPD) at the time. While the goal of every teacher is to provide appropriate support for learners to develop learning experiences to realise their full potential. It is also imperative to understand that learner must be coming from a place of inferior knowledge or assumptions. That said, there needs to be knowledge difference for learning to take place (MKO). NOS integrated instruction provides appropriate and deliberate pedagogical support to equip teachers on ways to better assist individual learner based on their peculiarities. According to Vygotsky, teaching precedes development, as such, adequate attention is deserved of science teacher training considering the advancements in pedagogical research in science and science education. Collaboration is essential in NOS integration as well as ZPD with respect to thinking, pairing and sharing of knowledge and ideas. In addition, inquiry and argumentation have roles in both NOS integration and ZPD in nurturing and automating a scaffold to assist learners. Teachers in training otherwise known as preservice teachers must be open enough to negotiate learning in their classrooms for learners' internalisation and autonomy. The state of science teaching research is an aberration from past practice in terms of expected outcomes from all learners. Knowledge currently is individualised and contextualised, as such, preservice and in-service teachers are now more than ever required to know the best ways to support learners to maximise their potentials.

Vygotsky's theory has since evolved to accommodate possibilities of potential development among learners of equal peers, less capable peers and those working alone within their ZPD using learning strategies. However, teachers as experts have the advantage of accommodating learners' views through discussion and collaboration especially among learners themselves. As teachers, recruiting learners' interest is imperative to mastery, as such, both cognitive and affective domains must be supported to assist learners in developing self-efficacy, motivation, engagement and willingness in a socially mediated space. With NOS integration, teachers are better equipped with the requisite capacity and skill to support the development of learners through culture, history and tradition of science that allows for mastery of not only the knowledge of science but the mastery of science processes. ZPD is not static, when properly guided, learner ZPD are more sensitive to learning. How intellectual development is assisted through social interaction with peers and expert (teacher) to remediate the inadequacy of learners in science is our focus.

Literature Review

For teachers of science and those in training (preservice teachers), the construct from which inferences are made on scientific issues for classroom practice is germane. Subsequently important, is the construction of explanations for learners' appropriate conceptualisation of socio-scientific issues and scientific literacy which is embedded in NOS. The essence of learning science is to be functional enough to take informed decision as literates. Positions in the literature are explored here to aggregate scholarly findings on NOS with respect to why, what and how it is necessary in classroom practices of science teachers. Alameh et al., (2023) researched quality of scientific explanation among scientist, science teachers and college students. Scientific phenomena as explained by the three categories of participant were analysed along the Nature of Scientific Explanations (NOSE). The study found scientist to provide superior explanations to scientific phenomena than teachers and college students. The type of explanations provided in the study by these categories share construct similarities but differs in dimensions. An analytical framework was devised in the study to examine the construct and types of scientific explanation which by implication could assist in the training of both teachers and preservice teachers of science on elements and constructs of scientific explanations.

In a similar study, Mesci et al., (2023) emphasized the need for early professional development of teachers in training by advancing argumentation-based NOS instruction influence on preservice teachers' views and practices in a single experimental design with multiple data sources-like Views on Nature of Science [VNOS] (Lederman et al., 2002), interview, argumentation-based NOS report and research note. Explicit reflective method was adopted over a two-semester period among 41 preservice teachers at a state university in Turkey. It was found that preservice teachers lesson planning and argumentation-based teaching improved significantly despite their inability to teach correctly at their first attempt. The study affirms the need for consistent practice of NOS knowledge in training for preservice teachers to perfect their NOS knowledge transfer to teaching. The position of Mesci et al., (2023) advanced the state of literature from Abd-El-Khalik and Akerson, 2004 which emphasized a conceptual change in the views of preservice teachers on NOS. Earlier study identified mediating factors which may hinder training while the later study avail literature the progress made so far in preservice teacher training on NOS and its integration.

Secondary science preservice teachers were examined along contextualised and decontextualised NOS instruction to elicit data on conception and instructional intentions by Bell et al., (2016). The study sampled from two cohort of seventy master of teaching program where participants had explicit instruction on NOS conceptions using varied degree of contextualised which accommodated conceptual change principle in the first year of instruction. Evaluation of pre- and post-conception was done using VNOS-C questionnaire (Lederman et al., 2002) and interview. Participants' conceptions were categorised based on degree of alignment with NOS conception. Unlike the present study which sought to evaluate rationale for NOS among preservice teachers with a separate instrument, Bell and colleagues sought and reported significance in alignment to NOS instruction between pre and post conception. There was a shift in the conception of participants to plan future NOS instruction with sufficient rationale for integration especially in the teaching of evolution. The research substantiates the need for scaffolding in NOS lessons to change conception and instructional intention of preservice teachers with recommendations for future research in post-method course and post-program NOS instruction.

Problem Statement

Strengthening preservice teachers' knowledge of the Nature of Science (NOS) to achieve a thorough understanding for deliberate and thoughtful integration into their future classroom practices has garnered attention from scholars (Alameh et al., 2023; Alameh et al., 2023). Within the realm of science education, teachers are expected to possess not only content knowledge but also pedagogical expertise to effectively convey scientific principles and processes to students in a genuine and meaningful manner. Recent perspectives in science education have favored explicit and reflective integration over implicit methods (McComas and Clough, 2018; Mesci, 2020; Mesci et al., (2023); Sweeney and McComas, 2022). As a result, there's an expectation for a shift in science education pedagogy to address uncertainties regarding scientific processes, cultural aspects, and socio-scientific issues among future educators (preservice teachers).

The existing environment of science teacher training in South Africa reflects elements of detached and implicit teachings on NOS. To progress towards explicit and contextualized NOS education in teacher training, a revaluation of the history and philosophy of science is necessary to introduce course content capable of enhancing preservice teachers' capabilities. Various dimensions have been explored in assessing preservice teachers' understanding of NOS during their professional training (Alameh et al., 2023; Alameh et al., 2023; Mesci et al., (2023)). The study focus sits in creating assessment tools pointing at the elements and rationale behind NOS for preservice teachers in their second and third years, aiming to evaluate the adequacy of their knowledge in this domain.

Aim

To devise and test assessment instruments to guide preservice teachers' training on Nature of Science elements and rationale.

Objectives

1. To devise templates to assess preservice teachers' knowledge of elements and rationale for NOS.
2. To validate assessment templates on elements and Rationale for NOS.
3. To investigate the effect of instructional intervention among preservice teachers' knowledge of elements and rationale for NOS.

Questions

1. Is the Assessment template on elements and rationale for NOS reliable across dimensions (Relevance, coherent and Clarity)?
2. Do preservice teachers possess adequate knowledge of element and rationale for NOS for eventual classroom integration?
3. Does difference exist in the knowledge of NOS integration between physical and life science preservice teachers?

Hypothesis

$H_{01:}$ Instructional intervention will not significantly influence preservice teachers' knowledge of elements and rationale for NOS.

H_{02}: There is no significant difference in the post-test score of physical and life science students' knowledge of elements and rationale for NOS.

Materials and Methods

Design

This study adopts quasi-experiment design of one-group pre-test and post-test design to evaluate preservice teachers' knowledge of elements and rationale for NOS from a positivist paradigm (Cohen, Manion and Morrison, 2020), to examine the effect of the review of course content in history and philosophy of science from second year to third year (two years intervention). The review included the knowledge of elements and rationale for NOS and Nature of Scientific Explanations [NOSE] (Stimulus).

Experimental O1 X O2

Context of the Study

One hundred and thirty-six second year Physical and Life Science education students from a public university were the participants in the study. Science pedagogy modules (History and Philosophy of Science) which spanned from second year to the third was the intervention (stimulus). Aspect of this study was embedded in second- and third-year courses on history and philosophy of science as part of course review to improve preservice teachers' didactic skills. Participants knowledge of element and rationale for NOS were tested before the commencement of the intervention to ascertain their level of knowledge on elements and rationale for NOS. The choice of these participant was informed by the need to update science preservice teacher training to accommodate contextualised, explicit and reflective NOS for their eventual classroom practices. Argumentation, inquiry and problem-based methods were favoured in students' presentation on assignments where they were divided into three groups. The grouping took into account spread in both physical and life sciences education by making sure that there was fair representation. One hundred and twelve (112) students were in life sciences and twenty-four in physical sciences education. The twenty-four participants were shared into three groups of eight (physical sciences), 37 participants each joined the first and second group while 38 participants joined the last group from students studying life sciences. Prior to the module review, History and Philosophy of science is a compulsory pedagogical course for second- and third-year preservice teachers. The course review added Nature of Science and Nature of Scientific explanations with emphases on argumentation, inquiry and Problem-based Methods.

The participants and the researchers (moderators/facilitators) agreed to select one difficult topic in Physical (Electricity & Magnetism) and two topics in Life sciences (Transport Systems in Mammals & Human Evolution) curricula at Further Education and Training [FET] phase of Curriculum and Assessment Policy Statement [CAPS] to accommodate integration of NOS, as well as construction of scientific explanations. The three groups were opportune to present on each of the three topics where moderators provided guidance. Each group were to use argumentation, inquiry and Problem-based Methods in each of the topic presentations at different times. i.e., each group employed one of the three methods for their presentation and assignments. For emphasis, learning outcome 3 on page 32 of physical sciences curriculum [https://www.education.gov.za/Portals/0/CD/SUBSTATEMENTS/Physical%20Science.pdf?ver=2006-08-31-122200-000] and life sciences [https://www.education.gov.za/Portals/0/CD/National%20Curriculum%20Statements%20and%20Vocational/CAPS%20FET%20_%20LIFE%20SCIENCES%20_%20GR%2010-12%20Web_2636.pdf?ver=2015-01-27-154429-123%20] on page 22 reiterated the need for NOS, construction and application of scientific knowledge.

Instruments

Table 1. *Internal consistency by experts across dimensions*

Dimensions	Clarity	Coherence	Relevance
Elements of NOS	.83	.91	.86
Rationale for NOS	.87	.90	.84

The criteria for selecting experts were- Ph.D. holders in Science Education, hold a faculty position in a department of science education or an equivalent in a university, must be teaching science pedagogy module for at least 2 year and should be willing to assess the instruments. A total of 15 experts judged the 12 items each on both elements and rationale for NOS. As shown on Table 1, the two instruments (ENOS & RNOS) were reliable as the internal consistency from the Cronbach's Alpha values across the dimensions of clarity, coherence and relevance show strong degree of agreement among experts. All the values obtained were above .70 in each of the instances indicating acceptable internal consistency and reliability.

Analysis

In the rating of the items, we assigned 1 to agree while neutral, disagree and don't know were assigned 0 in both ENOS and RNOS. Analysis was done using mean and standard deviation as descriptive statistics to make meaning of the research questions while inferential statistics of Analysis of Covariance (ANCOVA) and t-test was employed to test the hypotheses.

Procedure

The administration of the pretest (ENOS & RNOS) was done after the introductory class of the second year for all the participants. Data was coded in Microsoft Excel while the teaching of the reviewed course content History of Science (HOS) which included the introduction of NOS, scientific process and Nature of Scientific Explanations (NOSE) commenced. HOS is a prerequisite to third-year course titled Philosophy of Science (POS), wherein, a continuation of NOS, scientific process and NOSE were elaborated. Assignments and presentations were done by the groups on the selected topics. The researchers were moderators of the sessions. At the end of the classes in the third year, the instruments (ENOS & RNOS) were post-tested. The data obtained from the post-test was coded in Microsoft Excel and analysed with SPSS.

Ethical considerations

Participants voluntarily signed the consent forms to participate in this study. Purpose, procedure, confidentiality, risk, benefits, rights to volunteer as respondents were explained in the consent form. Pseudonyms were used to encrypt the identity of participants. This research was approved by the Ethical Committee of the University of the Free State with clearance number: UFS-HSD2022/1029/22/3.

Results

Table 2. *Descriptives and demography*

Participants		Mean	Std. Deviation	N
Pretest on Elements of NOS	Physical Sciences	3.08	1.640	24
	Life Sciences	2.61	2.072	112
	Total	2.69	2.006	136
Post-test on Elements of NOS	Physical Sciences	10.12	1.624	24
	Life Sciences	10.37	1.605	112
	Total	10.32	1.605	136
Pretest on Rationale for NOS	Physical Sciences	2.83	1.736	24
	Life Sciences	4.27	1.786	112
	Total	4.01	1.854	136
Post-test on Rationale for NOS	Physical Sciences	11.17	.637	24
	Life Sciences	11.57	1.096	112
	Total	11.50	1.040	136

A total of one hundred and thirty-six preservice teachers took part in this study. From the sample, one hundred and twelve of the participants were Life Sciences major while twenty-four of the respondents were majoring in Physical Sciences. Table 2 shows the demography is the participants as well as the pretests and post-tests on both elements and rationale for NOS. Deducible from Table 2, preservice teachers were not knowledgeable in both instances of elements and rationale in the pretest with their mean scores far below the average of 6 from 12 items in each of the instance. However, after the intervention, rapid improvement is noticeable through the mean scores which is above 10 within the two groups and in each of the instance.

Hypotheses Testing

H_{01}: Instructional intervention will not significantly influence preservice teachers' knowledge of elements and rationale for NOS.

Table 3. *t-test of pre and post-test on elements of NOS*

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Score Element	Equal variances assumed	9.209	.003	-34.650	270	.000
	Equal variances not assumed			-34.650	257.621	.000

Table 3 shows significant difference in the pre and post-test scores of preservice teachers on elements of NOS. The confidence interval in this case is 95% which implies that a test of significance is measured at $p< .05$. As seen on Table 3, the p value (.003) is less than .05. By implication, the null hypothesis is rejected. This means that there was significant difference between the pretest and post-test score of preservice teachers on elements of NOS as against the null hypothesis. Instructional intervention significantly influenced the knowledge on elements of NOS.

Table 4. *t-test of pre and post-test on rationale for NOS*

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Score Rationale	Equal variances assumed	50.113	.000	-41.067	270	.000
	Equal variances not assumed			-41.067	212.307	.000

Table 4 reports significant difference in the pre and post-test score of preservice teachers on rationale for NOS. The confidence interval in this case is also 95% which implies that a test of significance is measured at *p*< .05. From Table 4, the *p* value (.00) is less than .05. This means that the null hypothesis in this case is also rejected. There was significant difference between the pretest and post-test score of preservice teachers on rationale for NOS as against the null hypothesis. Instructional intervention had significant influence on preservice teachers' knowledge on rationale for NOS.

H_{02}: There is no significant difference in the post-test score of Physical and Life Science preservice teachers' knowledge of elements and rationale for NOS.

Table 5. *ANCOVA on elements of NOS*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	44.697a	2	22.348	9.807	.000	.129
Intercept	4414.794	1	4414.794	1937.412	.000	.936
TotalPrE	43.548	1	43.548	19.111	.000	.126
Students	.219	1	.219	.096	.757	.001
Error	303.068	133	2.279			
Total	14842.000	136				
Corrected Total	347.765	135				
a. R Squared = ,129 (Adjusted R Squared = .115)						

Table 5 reveals the analysis of covariance of post-test scores between preservice teachers of Life Science and Physical Science using the pretest as covariate on elements of NOS. From Table 5, the table value (.757) is greater than *p* value (.05). By implication, the hypothesis which states that there is no significant difference in the post-test score of Physical Science and Life Science preservice teachers' knowledge of elements of NOS is retained. No statistical significance is recorded in the post-test score of preservice teachers in both Life and Physical Science on element of NOS.

Table 6. *ANCOVA on rationale for NOS*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	14.290[a]	2	7.145	7.457	.001	.101
Intercept	3470.835	1	3470.835	3622.116	.000	.965
TotalPrR	13.817	1	13.817	14.419	.000	.098
Students	3.090	1	3.090	3.224	.075	.024
Error	127.445	133	.958			
Total	18266.000	136				
Corrected Total	141.735	135				

a. R Squared = .101 (Adjusted R Squared = .087)

Table 6 shows the analysis of covariance of post-test scores between preservice teachers of Life Sciences and Physical Sciences using the pretest as covariate on rationale for NOS. The table value

(.075) is slightly greater than *p* value (.05). Consequent from Table 6, the hypothesis which states that there is no significant difference in the post-test score of Physical Science and Life Science preservice teachers' knowledge on rationale for NOS is not rejected. Statistical significance is not recorded in the post-test score of preservice teachers in both Life and Physical Sciences on rationale for NOS.

Discussion

The aim of this study was to devise and test instruments to guide preservice teachers' training for improved teaching and eventually learning. Better prepared science teachers (with knowledge of [NOS & NOSE] have the potential to enhance the quality of teaching through explanations they afford their learners (Abd-El-Khalik and Akerson, 2004; Alameh et al., 2023). The knowledge of element and rationale for NOS could be assumed non-existent in the participants before the intervention in this study owing to the mean scores obtained in the pretest. Early professional training as done in this study for preservice science teachers on elements and rationale for NOS has proven to influence the views, conceptual change and practices of preservice teachers in the literature Mesci et al., (2023). While the studies of Mesci et al., (2023) and Lederman et al., 2002 measured intervention on professional development of preservice teachers through argumentation-based teaching and VNOS respectively, the intervention in this study took different approach, method and locale but all on NOS. Instructional intentions are expected to be pre-determined by teachers of science, as such, the development of preservice teachers to focus on knowledge negotiation with their learners through inquiry, argumentation and problem-based methods is encouraged. This intervention will allow for preservice teachers to contextualise future teaching within NOS to improve scientific literacy as posited in the study of Bell et al., (2016) on science method courses.

Positive outcome of the intervention in this study as relayed provide preservice teachers with enhanced capacity to better support learners as emphasised through Vygotsky' framework on MKO and ZPD. Furthermore, science education literature has supported efforts to enhance science teacher training through NOS as is in the studies of Mesci, 2020; Nouri and McComas, 2019, Yacoubian, 2021. Particularly and most recently, the studies of Alameh et al (2023), Khishfe (2022), Mesci et al., (2023) and Sweeney and McComas (2022) supported the position of this study on the need for and influence of NOS on preservice teachers' conceptual change, long-term retention, competency and quality of explanations constructed. Difficulties experienced by learners in science can be better managed through integration of NOS explicitly and contextually (Mesci, 2020). The intention of professional development is to influence classroom practices, however, measuring the impact of this development remains futuristic.

Integrating scientific practices in the classroom through NOS in preservice teacher training is encouraged in this study. Previous scholarly positions emphasised the need for teachers to be equipped with the knowledge of both elements and rationale for NOS (Clough, 2018; Lederman et al., 2002; Mesci et al., (2023); Nouri et al., 2021), as in this study. In addition, the teaching of the inter-relationship, appropriateness and quality of science knowledge require foundational basics for novice teachers and preservice teachers. Hence, the knowledge of NOS as examined in this study serves as a guide to the development of pedagogical skills required for competent science teacher training (Hanuscin, 2013; Mesci and Schwartz, 2017). Past and present literature have reported inadequacy in the knowledge of science content among novice and expert teachers, as well as the need to intensify efforts to resolve the inadequacy through training (Mulvey and Bell, 2017; Wahbeh and Abd-El-Khalick, 2014). However, content knowledge inadequacy may not be as impactful as pedagogical inadequacy. NOS provides a guide to narrate, discuss, inquire, argue and problematise the teaching of science to sustain interest, provide quality explanations and impact meaningfully and contextually.

Conclusion

Preservice teachers training on NOS remains germane to improving the quality of explanations constructed and conceptualisation for meaningful learning in science. Practical approach to explanations through argumentation, inquiry and problem-based approaches enhanced preservice teachers' preparation for eventual classroom practice. Admittedly, the instruments (ENOS & RNOS) were to provide a foundational template to understanding and assess the knowledge of science among preservice teachers. However, the presentations allowed for moderators to assist preservice teachers to improve the quality of explanations in the three topics trailed. These instruments assisted in assessing preservice teachers' knowledge of elements and rationale for NOS before and after the intervention.

Contribution to Teaching and Learning

Teachers are most likely going to teach the way they are taught. Better prepared teachers have the potential to impact qualitative learning. This study contributes to science teacher training for improved explanation and classroom practice. The instrument designed and the rating provides a newer way to assess preservice teachers' knowledge of elements and rationale for NOS. Testing preservice teachers' knowledge in these areas over 2 years proved significant improvement in their knowledge. The group assignments and presentation allowed for practical demonstration of their knowledge within inquiry, argumentation and problem-based methods which assisted their ability to construct scientific explanations for their eventual classroom practice at the fourth/final year for teaching practice and further practice.

Author Contributions

Olalekan Taofeek Badmus - Conceptualization, methodology, formal analysis, writing—original draft preparation; Loyiso C. Jita - writing—review and editing, Validation, Funding acquisition. All authors have read and agreed to the published version of the manuscript.

Conflict of interests

The authors declare no conflict of interest.

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